A COMPLETE TREATISE ON ELECTRICITY, IN THEORY AND PRACTICE; WITH ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE FOURTH EDITION,

IN THREE VOLUMES;

Containing the Practice of MEDICAL ELECTRICITY, besides other Additions and Alterations.

THE THIRD VOLUME IS ENTIRELY NEW,

And contains the Discoveries *and* Improvements *made since the Third Edition.*

VOLUME I.

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THE

PREFACE.

THE deſign of the following Treatiſe is, to preſent to the Public a comprehenſive view of the preſent ſtate of ELECTRICITY, reduced into as ſmall a compaſs as the nature of the ſcience would admit. It is divided into *five parts*, in each of which are contained ſuch particulars, as had leſs connection with

the reſt; and the diſtinct view of which, it was thought, might be a means of preventing a confuſion of ideas in the minds of thoſe readers, who before have not been much converſant with the ſubject.

The *firſt part* treats of the Laws of Electricity only; *i. e.* of ſuch natural laws concerning Electricity, as, by innumerable experiments, have been found uniformly true, and are independent on any hypotheſis. In this part, the Author has not deſcended to any particulars, which were not clearly aſcertained, or which were inconſiderable; but he has, at the ſame time, taken care not to omit any thing material,

material, or which ſeemed to promiſe future diſcoveries.

The *ſecond part* is merely hypothetical; relating not to facts, but to opinions. The great improbability of moſt of theſe hypotheſes determined the Author to render this part of his work as ſhort as poſſible.

The *third part* contains the practical branch of Electricity. Here the Author has taken care to inſert a deſcription of all the new improvements in the apparatus; which ſerve to leſſen the expence of it, and at the ſame time to facilitate the performance of the ex-

periments. As to the experiments themſelves, he has chiefly inſiſted on a few principal ones, which ſeemed moſt neceſſary to illuſtrate and confirm the laws of Electricity; omitting a great number of others, which he has met with, as they appeared to be only variations of the former. He has however given an account of ſome others, which, though not abſolutely neceſſary, ſeemed very deſerving of notice.

The *fourth part* contains a brief account of the principal experiments, which have been made by the Author himſelf, in purſuance of what occurred to him in the

courſe

courſe of his ſtudies in this branch of philoſophy. In this part he has omitted to mention, not only thoſe attempts, which did not produce any conſiderable effect, but alſo the innumerable conjectures he formed about them and others, not yet brought to the teſt of actual obſervation.

The *fifth part* contains the practice of Medical Electricity, which was formerly printed by itſelf.

The Author takes this opportunity of acknowledging the obligations he is under to ſeveral of his ingenious friends, for various experiments, and remarks, communicat-

ed by them; and particularly to the late Mr. WILLIAM HENLY, who did as much as laid in his power to inform him of every particular, which he thought would enrich and embelliſh the work.

It was deemed unneceſſary to point out thoſe gentlemen, whoſe experiments and obſervations introduced in this work, were before well known to the world; for which reaſon the Author has confined himſelf to the mention of the names of thoſe perſons, whoſe experiments were new, or not commonly noticed by the writers on this ſubject.

The

The third edition was enriched by various new and intereſting particulars, which were diſperſed throughout the work; but ſince that time divers improvements, and many very remarkable diſcoveries, have been made relative to the Science of Electricity, amongſt which we muſt reckon the ſurpriſing ſubject of Animal Electricity. It became therefore neceſſary to add thoſe diſcoveries and improvements to the work; and in order to accommodate the poſſeſſors of the third edition, the firſt and ſecond volumes have been reprinted without any material alteration, whilſt the new particulars have been collected in a third volume, which may

be had by itſelf, as well as with the other two volumes.

To render the Treatiſe more intelligible and uſeful, ſix copper-plates are added to it; and a copious Index of the particulars which are moſt deſerving of attention.

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INTRO-

INTRODUCTION.

ARTS and ſciences, like kingdoms and nations, have each in their turn ſome happy period of glory and ſplendor, in which they more than ever attract the human attention, and, by caſting a ſtronger light than at other times, become the favourite object and purſuit of the age; but theſe periods are ſoon over, and a few years of luſtre and fame are often overbalanced by centuries of oblivion. From undergoing this fate, ſome ſciences are, however, excepted, which, owing to the vaſt and neceſſary extent of their uſe, and to the fruitfulneſs of their productions, are ever flouriſhing; and although once unknown, yet when fame had proclaimed their birth, or publiſhed their advancement, they never afterwards declined. Of this kind is Electricity, one of the moſt pleaſing and

ſurpriſing among all the branches of natural philoſophy that ever were cultivated by man. This ſcience, after it began to ſhew the extent and generality of its power; after it was known to be one of the greateſt agents of nature; remained always in vogue, was profitably cultivated, irremittedly advanced, and is now brought to a ſtate, in which, inſtead of becoming ſterile, it ſeems further to engage the general attention, and to promiſe to its followers more munificent rewards. Optics, indeed, ſhews many enchanting and uſeful properties, but concerning viſion only; Magnetiſm exhibits the force of attraction, repulſion, and polarity in that ſubſtance called a Magnet: but Electricity, containing, as it were, all within its power, alone exhibits the effects of many ſciences, combines together different powers, and, by ſtriking the ſenſes in a particular and ſurpriſing manner, affords pleaſure, and is of uſe to the ignorant as well as the philoſopher, the rich as well as the poor. In Electricity, we are pleaſed with beholding its penetrating light, exhibited in numberleſs different forms; we admire its attraction and repulſion, acting

upon

upon every kind of body; we are ſurpriſed by the ſhock, terrified by the exploſion and force of its battery; but when we conſider and examine it as the cauſe of thunder, lightning, aurora borealis, and other appearances of nature, whoſe direful effects we can in part imitate, explain, and even avert, we are then involved in a maze, that leaves nothing to contemplate but the inexpreſſible and permanent idea of admiration and wonder.

The earlieſt account we have of any known electrical effect, is by the famous antient naturaliſt THEOPHRASTUS, who flouriſhed about 300 years before the preſent æra. He tells us that *amber* (whoſe Greek name is ηλεκτρον, and from whence the name *Electricity* is derived) as well as the *lyncurium**, has the property of attracting light bodies. This was all that was known of the ſubject, for about fifteen

* It hath been in a manner proved, that the *lyncurium* of THEOPHRASTUS is the very ſame ſubſtance that now goes under the name of *Tourmalin*; of which we ſhall have occaſion to ſpeak in the courſe of this Treatiſe.

teen centuries after THEOPHRASTUS; in which long period we find no mention in hiſtory of any perſon having made any diſcoveries, nor even any experiments in this branch of philoſophy; the ſcience remaining quite in the dark till the time of WM. GILBERT, an Engliſh phyſician, whoſe work *de magnete*, which contains ſeveral electrical experiments, was publiſhed in the year 1600; and who, for his diſcoveries in this new and uncultivated field, may be juſtly deemed the father of the preſent Electricity. He obſerved, that the property of attracting light bodies, after rubbing, was not peculiar to amber, or the *lyncurium*; but that many other bodies poſſeſſed it as well as amber. He mentions a great number of thoſe, together with many particulars, which, conſidering the ſtate of the ſcience at that time, may be deemed truely great and intereſting.

After GILBERT, the ſcience advancing, although by ſmall degrees, paſſed, as it were, from infancy to puerility; many an excellent philoſopher undertaking to examine nature in this walk: ſuch was Sir

FRANCIS

Francis Bacon, Mr. Boyle, Otto Guericke, Sir Isaac Newton, and moſt of all Mr. Hawkesbee, a perſon to whom we are much indebted for many important diſcoveries, and a real advancement of Electricity. Mr. Hawkesbee was the firſt who obſerved the great electric power of glaſs; a ſubſtance, that, ſince his time, has been generally uſed by all Electricians, in preference to any other electric. He firſt remarked various appearances of the electric light, and the noiſe accompanied with it, together with a variety of phenomena relating to electric attraction and repulſion.

After Mr. Hawkesbee, the ſcience of Electricity, however hitherto advanced, remained for about twenty years in a ſtate of quieſcence, the attention of philoſophers being at that time engaged in other philoſophical ſubjects, which, on account of the new diſcoveries of the incomparable Sir Isaac Newton, were then greatly in repute. Mr. Grey was the firſt, after this period of oblivion, to bring the ſcience again to light. He, by his great diſcove-

ries,

ries, re-introduced it to the acquaintance of philoſophers, and from him the true flouriſhing era of Electricity may be ſaid to take its date.

The number of Electricians that hath been daily multiplying ſince Mr. GREY, the diſcoveries made, and the uſe derived from thoſe, till the preſent time, are matters really worthy of attention, and deſerve to be admired by every lover of the ſciences, and well-wiſher to the human race.

Whoever would make himſelf acquainted with the particular tranſactions concerning thoſe advances, ſhould read the elaborate Hiſtory of Electricity compiled by the learned Dr. PRIESTLEY, a work that will inform him of whatever had been done relative to the ſubject till its publication. I, for my part, muſt forbear making any long hiſtorical detail; this treatiſe being intended to give an account of the preſent ſtate of Electricity, in a methodical manner, and not an hiſtory of the ſame. I ſhall in general only obſerve, that although the ſcience

ſcience had, through the indefatigable attention of ſo many ingenious perſons, and by the diſcoveries that were daily produced, excited the curioſity of philoſophers, and engaged their attention; yet, as the cauſes of any thing, whether ſmall or great, known or unknown, are ſeldom much attended to, if their effects are not ſtriking and ſingular; ſo Electricity had, till the year 1746, been ſtudied by none but Philoſophers. Its attraction could in part be imitated by a loadſtone; its light by a phoſphorus; and, in ſhort, nothing contributed to make Electricity the ſubject of the public attention, and excite a general curioſity, until the capital diſcovery of the vaſt accumulation of its power, in what is commonly called the *Leyden phial*, which was accidentally made in the memorable year 1745*. Then, and not till then, the ſtudy of Electricity became general, ſurpriſed every beholder, and invited to the

* This great diſcovery was made by Mr. VON KLEIST, Dean of the Cathedral in Comin. See the third edition of Dr. PRIESTLEY's Hiſt. of Elect. Per. VIII. Sect. 1.

houſes

houſes of Electricians a greater number of ſpectators, than were before aſſembled together to obſerve any philoſophical experiments whatſoever.

Since the time of this diſcovery, the prodigious number of Electricians, experiments, and new facts that have been daily produced from every corner of Europe, and other parts of the world, is almoſt incredible. Diſcoveries crouded upon diſcoveries; improvements upon improvements; and the ſcience ever ſince that time went on with ſo rapid a courſe, and is now ſpreading ſo amazingly faſt, that it ſeems as if the ſubject would be ſoon exhauſted, and Electricians arrive at an end of their reſearches: but, however, the *ne plus ultra* is, in all probability, as yet at a great diſtance, and the young Electrician has a vaſt field before him, highly deſerving his attention, and promiſing further diſcoveries, perhaps equally, or more important than thoſe already made.

A Com-

A

COMPLETE TREATISE

ON

ELECTRICITY.

PART I.

FUNDAMENTAL LAWS OF ELECTRICITY.

CHAP. I.

Containing the Explanation of ſome Terms principally uſed in Electricity.

IF a perſon, holding with one of his hands a clean and dry glaſs tube, rubs it with his other hand, alſo clean and dry, ſtroking it alternately upwards and downwards; and after a few ſtrokes, preſents to it ſmall light bits of paper, thread, me-

tal, or any other ſubſtance, the rubbed tube will immediately attract them, and after a little time will repel them—preſently, attract them again; and ſo alternately continue this attraction, and repulſion, for a conſiderable Time. If this tube be rubbed in the dark, and, after having been rubbed, a finger be preſented to it at the diſtance of about half an inch, a lucid ſpark will be ſeen between the finger and the tube, accompanied with a ſnapping noiſe; the finger at the ſame time receiving a puſh, as if it were from air iſſuing with violence out of a ſmall pipe.

In this experiment, the attraction, repulſion, ſparkling, &c. are the effects of that unknown cauſe called *Electricity*; and hence they are called *electrical appearances*. The glaſs tube itſelf is called the *electric*, and all thoſe bodies which are capable by any means to produce ſuch effects, are called *electrics*; and as the rubbing awakes, as it were, in them the power of producing electrical appearances, they are therefore ſaid to be *excited* by the rubbing. The hand, or any other body that rubs an

electric,

electric, is called the *rubber*; and if, instead of the perfon rubbing the glafs tube, a machine be conftructed capable by any means to excite an electric, this will be an *electrical machine*.

If at the end of the tube oppofite to that held by the hand, a wire of any length be tied, fufpending a metallic ball at its end, and the tube be excited as before, the metallic ball will, in this cafe, acquire all the properties of the excited tube, *i. e.* it will attract, fparkle, &c. like the tube itfelf, the electric virtue paffing through the wire to the ball: hence, the wire is faid to be a *conductor* of electricity; and all fuch bodies as are capable to tranfmit the electric virtue, like the above-mentioned wire, are called *conductors*.

But if, inftead of the wire, a filk ftring be ufed in the above experiment, and the tube be excited as before, the ball in this cafe will not fhew any figns of Electricity; the filk ftring not permitting the electric virtue to pafs from the tube to the ball:

hence the ſilk ſtring in this caſe, and all thoſe ſubſtances through which the electric virtue cannot be tranſmitted, are called *non-conductors*.

A body reſting intirely upon non-conductors is ſaid to be *inſulated*; ſo, in the laſt experiment, the metallic ball was inſulated; ſince it was ſuſpended intirely by the ſilk ſtring, which is a non-conductor. The bodies which are conductors, and thoſe which are non-conductors of electricity, together with their peculiar properties, as far as they are known, will be plainly laid down in the following chapters.

CHAP.

CHAP. II.

Of Electrics and Conductors.

THE first and principal maxim in Electricity is, that all the known bodies in nature are divided into two classes, viz. Electrics and Conductors; experiments shewing, that whatever substance is a Conductor of Electricity, cannot be excited, (hence Conductors are also called *Non-electrics)*; and that whatever substance can be excited, is not a Conductor, (hence *Electrics* and *Non-conductors* become synonymous terms*.) This maxim, however, is not to be considered as strictly true and general; for in reality we know of no substance that may be called a perfect Electric, nor of any that may be called a perfect Conductor; the Electric virtue finding some resistance in going through the best Conductors, and being in part transmitted through, or over the surface of most, and perhaps all the Electrics. The less per-

* Electrics are often also called *Electrics per se.*

fect Conductor any fubftance is, the nearer it comes to the nature of an Electric; and, on the other hand, the lefs perfect Electrics come neareft to the nature of Conductors. The limits of thofe two claffes come fo far one within the other, that there are many fubftances which may be actually excited, and at the fame time are pretty good Conductors. If the reader defires to know thofe ambiguous fubftances, he muft feek for the worft Electrics among the Electrics, and for the worft Conductors among the Conductors, excepting fuch on which the experiment cannot be tried, as fluids, powders, &c.

The two following lifts contain, in general, all the Electrics and Conductors, difpofed in the order of their perfection, beginning in each lift with the moft perfect of their clafs. In this order, however, the reader muft not expect a great exactnefs; that being impracticable, when fubftances are fet under general articles; and at the fame time is of little, if indeed of any ufe whatever.

ELECTRICS.

ELECTRICS.

Glaſs, and all vitrifications, even thoſe of metals.

All precious ſtones, of which the moſt tranſparent are generally the beſt.

All reſins *, and reſinous compounds.

Amber.

Sulphur.

Baked wood.

All bituminous ſubſtances.

Wax.

Silk.

Cotton.

All dry animal ſubſtances, as feathers, wool, hair, &c.

Paper.

White ſugar, and ſugar-candy.

Air.

* Under the name of reſins, I would be underſtood to mean all ſuch conſiſtent, oily, vegetable, productions as are inflammable, and not ſoluble in water; gum-lac, therefore, and all ſuch ſubſtances, improperly called gums, are alſo meant under this article. See MACQUER's Chemiſtry, vol. i. chap. 11.

Oils *.

Calces of Metals and ſemi-metals.

The aſhes of animal and vegetable ſubſtances.

All dry vegetable ſubſtances.

All hard ſtones, of which the hardeſt are the beſt.

Many of the above-mentioned ſubſtances, and perhaps all thoſe upon which the experiment can be made, when very hot, loſe their electric property, and become quite, though not equally good, Conductors; ſo red-hot glaſs, melted reſin, hot air, baked wood made very hot, &c. become Conductors of electricity. But it is very remarkable, that the focus of a burning-glaſs is not a Conductor of electricity. It has been obſerved, that glaſs, eſpecially the hardeſt and beſt vitrified, is often a very bad Electric, ſometimes being quite a Conductor. The Abbé Nollet and others have made various experiments relative to this property of glaſs, but without determining

* Mr. CIGNA obſerved electrical attraction and repulſion between conducting ſubſtances plunged in oil. NOLLET's Letters, vol. iii. p. 168.

mining intirely the caufes which occafion the difference. Glafs veffels, made for electrical purpofes, are often rendered very good Electrics by ufe and time, though they might be very bad ones when new. On the other hand, fome glafs veffels, which had been long ufed for excitation, have fometimes loft their power almoft intirely. I remember to have obferved two indifputable inftances of this fort.

A glafs veffel, out of which the air has been exhaufted, on being rubbed, fhews no figns of electricity upon its external furface, but all the electric power appears within the veffel*; and a glafs tube, or globe, with the air condenfed in it, or full of fome conducting fubftance, is incapable of being excited. But a folid ftick of glafs, of fealing wax, &c. may be excited.

* Although a glafs veffel, exhaufted of air, does not fhew any figns of electricity without; yet it has been obferved, that the electric power of a glafs cylinder is the ftrongeft, when the air within it is a little rarefied, *viz.* fomewhat lefs denfe than the external air. See l'Elettricifmo Artificiale of G. B. BECCARIA, § 411.

CONDUCTORS.

CONDUCTORS.

Gold.

Silver.

Copper.

Brass.

Iron.

Tin.

Quickfilver.

Lead.

Semi-metals.

Ores; of which the beft are thofe that contain the metallic part in the greateft quantity, and come neareft to a metalline ftate.

Charcoal, made either of animal or of vegetable fubftances.

The fluids of an animal body.

All fluids, excepting air and oils *.

The effluvia of flaming bodies.

Ice †.

Snow.

* Salt water is a better Conductor than frefh water.

† Mr. ACHARD, being at Berlin, in the month of January 1776, obferved, that water froze to the twentieth degree below 0 of Reaumur's thermometer (which

Snow.

Moſt ſaline ſubſtances, of which the metallic ſalts are the beſt.

Stony ſubſtances, of which the hardeſt are the worſt.

Smoke.

The vapour of hot water.

Electricity pervades alſo vacuum, or the abſence of air cauſed by an air-pump, al-

(which anſwers to the thirteenth degree below 0 of Fahrenheit's ſcale) was an electric. He tried his experiments in the open air, where he found that a rod of ice two feet long, and two inches thick, was a very imperfect Conductor, when Reaumur's thermometer was at ſix degrees below 0, and that it would not in the leaſt conduct, when the thermometer was at 20°. By whirling a ſpheroid of ice in a proper machine, he even electrified the prime conductor, ſo as to attract, repel, give ſparks, &c. The ice that this gentleman made uſe of, was free from bubbles of air, and quite tranſparent; to produce which, he uſed to ſet a veſſel, containing diſtilled water, to be frozen, upon the window of a room, which was rather warm with reſpect to the ambient air; where the water began to freeze on one ſide of the veſſel, while on the other ſide it was ſtill liquid; in which caſe, he ſays that the bubbles of air ſeparated from the part of the water that began to freeze firſt, and paſſed gradually into the liquid part, ſo as to leave a conſiderable thickneſs of ice quite tranſparent.

moſt as freely as the ſubſtance of a good Conductor *.

Beſides theſe, all bodies, in which more or leſs of ſome of the above-mentioned Conductors are contained, are alſo proportionably Conductors; thus, green vegetables, raw meat, &c. are Conductors, on account of the fluids they contain.

From this principle it follows, that all Electrics, before excitation, ſhould be well cleaned, dried, and ſome made even very hot, in order to free them from every humidity; otherwiſe they are ſo far from the nature of Electrics, that they become actually Conductors, on account of the

* "I beg leave to mention in this place, as favourable to this hypotheſis, a moſt curious diſcovery made very lately by Mr. WALSH; who, being aſſiſted by Mr. de LUC to make a more perfect vacuum in the double or arched barometer, by boiling the quickſilver in the tube, found that the electric ſpark or ſhock would no more paſs through it, than through a ſtick of ſolid glaſs.—Dr. PRIESTLEY's Exp. and Obſ. on different Kinds of Air, vol. i. p. 284. Farther experiments and obſervations of the author and others, concerning the conducting or non-conducting power of a vacuum, will be found towards the end of this Work.

moiſture

moiſture which they contain within their pores, or upon their ſurfaces.

In regard to the conducting power of charcoal, it muſt be obſerved, that all charcoal will not conduct equally well, there being ſome that will hardly conduct at all; and ſometimes is in ſuch a ſtate, that it will aſſiſt the paſſage of a large quantity of electric fluid along its ſurface, when it will not conduct it any other way. This difference, however, is not occaſioned by the difference of the wood from which the coals are made, but by the degree of heat that is applied in the proceſs of making them; the beſt Conductors being ſuch as have been expoſed to the greateſt heat *.

Whether the piece of wood in the proceſs of coaling is ſuffered to flame, or not, is quite immaterial; and the continuance of the ſame degree of heat has no apparent effect with reſpect to the conducting power of the charcoal.

* See Dr. PRIESTLEY's ſecond volume of Obſervations on different Kinds of Air, Sec. xiv.

It

It will not be improper to obſerve in this place, the different changes from Conductor to Non-conductor, occaſioned in the ſame ſubſtance by different preparations. A piece of wood juſt cut from a tree is a good Conductor; let it be baked, and it becomes an Electric; burn it to a coal, and it is a good Conductor again; laſtly, let this coal be reduced to aſhes, and theſe will be impervious to electricity. Such changes are alſo obſervable in many other bodies; and very likely in all ſubſtances there is a gradation from the beſt Conductors to the beſt Non-conductors of Electricity.

CHAP.

CHAP. III.

Of the two Electricities.

IF, in the experiment mentioned in the first chapter, the person that rubs the tube be insulated, *i. e.* be set with his feet upon a cake of resin, a stool with glass feet, or any other good Electric, so that the communication between his body and the earth be cut off by means of Electrics; and if in this situation he rubs the tube with his hand, as before; this person, as well as the tube, will, in this case, appear electrified. If any light bodies be presented to any part of his body, they will be attracted and repelled. If another person presents his finger to him, a lucid spark will follow, with a snapping noise; and, in short, this insulated person will shew every sign of electricity that the tube exhibits. But their electricities are not the same; the electricity of the tube being just the reverse of the electricity of the person: and their particular appearances are the following;

1. Whenever

1. Whenever a light body inſulated, as, for inſtance, a ſmall piece of cork ſuſpended by a ſilk thread, has been attracted by the tube, and afterwards repelled, if no conducting ſubſtance touches it in this ſtate of repulſion, it will not be attracted by the tube again. The ſame happens with the inſulated perſon; for when this light body has been once attracted by any part of his body, and afterwards repelled, it will not be attracted again; but if in this ſtate of repulſion the tube be preſented to it, then it will be attracted, and that violently, by the tube; and when repelled by the tube, it will be attracted by the inſulated perſon. Further, if two or more light inſulated bodies, like the abovementioned piece of cork, be ſeverally attracted by the tube, and when afterwards repelled, be brought within a ſmall diſtance of one another, they will repel each other, and, if well inſulated, continue in this electrified and repulſive ſtate for a conſiderable time. The ſame will happen, if they be preſented to the perſon inſtead of the tube; they will alſo, after being once repelled by this, repel one another. But, if

if one, or more of thoſe light inſulated bodies be attracted and repelled by the tube; and one or more others be attracted and repelled by the perſon, and afterwards both or all (*i. e.* ſuch as were preſented to the tube, and ſuch as were preſented to the inſulated perſon) be brought within a ſufficient diſtance of one another, they will then, inſtead of repelling, attract each other; and inſtead of continuing electrified, extinguiſh at once every ſign of electricity. Theſe two electricities, therefore, are (as was ſaid before) the one juſt the contrary of the other, the one attracting what the other repels; and, as if one was an affirmative, and the other a negative power, when equal quantities of each are ſummed together, they balance each other, and loſe every property.

2. Another characteriſtic of each of the two electricities, conſiſts in the appearance of their light. If a pointed body, as a needle, a wire, or the like, be preſented to the excited tube in the dark, a lucid globule, like a ſtar, will be ſeen upon the point; but if this pointed body be preſented to the inſulated perſon, then in the

place of the ſtar a lucid pencil appears, compoſed of rays, ſeemingly iſſuing from the point, and diverging towards the perſon *.

3. Laſtly, in ſome experiments (which will be hereafter particularly mentioned, and this property better explained) the electricity of the tube, when in the act of paſſing from a body overcharged with it to another, either not electrified, or poſſeſſed of the contrary electricity, ſhews an indiſputable current from the former to the latter; and the electricity of the inſulated perſon, when in the act of paſſing from a body overcharged with it to another, either not electrified, or poſſeſſed of the contrary electricity, ſhews clearly a current from the latter to the former.

Theſe two electricities are not only obſerved in the above-mentioned experiment, but in ſeveral other caſes alſo; and they always accompany each other; for when

* This pencil of rays will appear better, if a pointed needle be preſented to the inſulated perſon, at the diſtance of about one inch from ſome part of his body, while he is actually rubbing the tube in the dark.

different

different Electrics are rubbed, ſome will acquire one electricity, and others will acquire the contrary; the rubber, if inſulated, ſhewing at the ſame time ſigns of the electricity contrary to that acquired by the excited electric: beſides this, almoſt all Electrics may be made to ſhew at pleaſure the one or the other electricity, according to the ſubſtance uſed for a rubber. Hence the following corollaries may be deduced: *viz.* 1 Whenever two different ſubſtances (being both inſulated, or only that which is a Conductor) are rubbed together, except they are both equally good Conductors, they will be both electrified, and one acquire the electricity contrary to the electricity of the other. 2. Almoſt all the Electrics may be made to acquire, at pleaſure, the one or the other electricity by uſing proper rubbers.

The firſt of theſe two electricities, *i. e.* that poſſeſſed by the glaſs tube in the above experiment, as it was thought to be the conſtant production of rubbed glaſs, was called the *Vitreous Electricity*; and the other, as it was firſt obſerved to be produced by reſinous ſubſtances, was called

the *Resinous Electricity*. The Vitreous Electricity is also called *Positive* or *Plus Electricity*, for a reason that will be considered in the course of this Treatise; and the Resinous is called also *Negative* or *Minus Electricity*. A body, therefore, possessed of the Vitreous, Positive, or Plus Electricity, is that which shews such signs as the tube was said to exhibit; and a body possessed of the Resinous, Negative, or Minus Electricity, is that which shews such signs as the insulated person was said to exhibit in the above-mentioned experiment.

In the following Table may be seen what Electricity will be excited in different bodies, when rubbed with different substances. Smooth glass, for instance, will be found by this Table to acquire a Positive Electricity, when rubbed with any substance hitherto tried, except the back of a cat (by which I mean the skin of a cat while on the animal alive); rough glass, *viz.* glass the polish of which has been destroyed by emery or otherwise, will be found to acquire the Positive Electricity, when rubbed with dry oiled silk, sulphur, &c. and the Negative,

when rubbed with woollen cloth, the hand, &c. and ſo of the reſt.

The back of a cat	Poſitive	Every ſubſtance with which it has been hitherto tried.
Smooth glaſs	Poſitive	Every ſubſtance hitherto tried, except the back of a cat.
Rough glaſs *	Poſitive	Dry oiled ſilk, ſulphur, metals.
	Negative	Woollen cloth, quills, wood, paper, ſealing-wax, white-wax, the human hand.
Tourmalin	Poſitive	Amber, air †.
	Negative	Diamond, the human hand.
Hare's ſkin	Poſitive	Metals, ſilk, loadſtone, leather, hand, paper, baked wood.
	Negative	Other finer furs.
White ſilk	Poſitive	Black ſilk, metals, black cloth.
	Negative	Paper, hand, hairs, weaſel's ſkin.
Black ſilk	Poſitive	Sealing-wax.
	Negative	Hare's, weaſels, and ferret's ſkin, loadſtone, braſs, ſilver, iron, hand.
Sealing-wax	Poſitive	Metals.
	Negative	Hare's, weaſel's, and ferret's ſkin, hand, leather, woollen cloth, paper.
Baked wood	Poſitive	Silk.
	Negative	Flannel.

* Glaſs may be made rough by rubbing it with ſand, or emery.

† i. e. By blowing with a pair of bellows upon it. By this means many Electrics may be ſenſibly excited, and ſome better if the air blown is hot; although, in both caſes, very little Electricity can be obtained.

The preceding Table might have been much extended, had I chosen to bring into it all the minutiæ attending this matter as far as is known; but this I have thought unnecessary and impracticable, because experiments of this kind are of so nice a nature, that they require the most scrupulous attention in making them; and then their effects depend upon so small and variable circumstances, that often the very same Electric, rubbed with the same rubber, gives at one time signs of one Electricity, and at another time signs of the contrary. A very little alteration in the surface, a different degree of dryness, and even a different application of the same substances, often occasions a difference in the Electricity. I shall only observe in general, that as far as may be deduced from the greatest number of experiments, it appears, that when different substances are rubbed together, that whose Electric power is the strongest, in general acquires the Positive, and the other the Negative Electricity; and when two bodies, differing in the smoothness or roughness of their surfaces, are rubbed together, the smoothest acquires the Positive, and the

the roughest the Negative Electricity. These two qualities are often to be considered both together; for, except the two bodies are of the same substance, as smooth and rough glass, white and black silk, &c. they generally differ in both, *viz.* they have not the same electric power, and at the same time their surfaces differ in smoothness. This rule, however, is not to be considered as a constant and general one; for, according to this principle, it should seem that a piece of sealing-wax, when rubbed with the hand, or paper, would acquire the Positive Electricity; but this is contrary to experience.

In case that two electric substances, equal in every respect, are rubbed together, it is to be observed that the substance which suffers the greatest friction acquires the Negative, and the other the Positive Electricity. Suppose, for instance, that a piece A of silk be drawn across another piece of silk B, in every respect equal to the former, so that the surface of the whole piece A, *i. e.* of one side of it, be successively drawn over one part of the piece B, then A will acquire the Positive, and B the Negative Electricity. The

reaſon of this may probably be, becauſe the part of the piece B, over which the piece A has been drawn, has acquired a greater degree of heat; for it has been obſerved, that heat rather diſpoſes bodies to be electrified Negatively.

CHAP. IV.

Of the different Methods of exciting Electrics.

RUBBING, as we obſerved before, is the general mean by which all electric ſubſtances that are at all excitable, may be excited. Whether they be rubbed with Electrics of a different ſort, or Conductors, they always ſhew ſigns of Electricity, and in general ſtronger when rubbed with Conductors, and weaker when rubbed with Electrics. But beſides friction, there are other means by which ſome Electrics may be cauſed to ſhew electric appearances: theſe are, by melting, or pouring a melted Electric into another ſubſtance; by heating or cooling; and by evaporating or effervesſcing. The particulars obſerved by uſing the firſt of theſe two methods are the following:

If

If ſulphur be melted in an earthen veſſel, and left to cool upon Conductors: if taken out of the veſſel, when cold, it will be found ſtrongly electrical; but not at all ſo, if it be left to cool upon Electrics.

If ſulphur be melted in glaſs veſſels, and afterwards left to cool, they will both acquire a ſtrong Electricity, the ſulphur Negative, and the glaſs Poſitive, whether they be left to cool upon Electrics or Conductors; however, they always acquire a ſtronger power in the former caſe than in the latter; and a ſtronger ſtill, if the glaſs veſſel is coated with metal. It is remarkable, that the ſulphur acquires no electricity till it begins to cool; its power increaſes in proportion as it contracts, and is the ſtrongeſt when in the ſtate of greateſt contraction; but then the electricity of the glaſs veſſel is at the ſame time the weakeſt.

If melted ſulphur be poured into a veſſel of baked wood, it acquires a Negative, and the wood a Poſitive Electricity; but if it be poured into ſulphur, or rough glaſs, it acquires no ſenſible electricity.

Melted

Melted ſulphur poured into a metal cup, and there left to cool, ſhews no ſigns of Electricity whilſt in the cup; but if they are ſeparated, they will then appear ſtrongly electrified, the ſulphur Plus, and the cup Minus, If the ſulphur is again replaced in the cup, every ſign of Electricity will vaniſh; but if, whilſt they are ſeparate, the Electricity of either of them is taken off, they will both, on being replaced, appear poſſeſſed of that Electricity which has not been taken off.

Melted wax, poured into glaſs, or wood, acquires a Negative Electricity, and leaves the glaſs or wood Poſitive. But ſealing-wax poured into ſulphur, acquires a Poſitive Electricity, and leaves the ſulphur Negative.

Chocolate, freſh from the mill, as it cools in the tin pans in which it is received, becomes ſtrongly electrical: when turned out of the pans, it retains for ſome time this property, but ſoon loſes it by handling. Melting it again in an iron ladle, and pouring it into the tin pans as at firſt, will for once, or twice, renew the power; but,

when the maſs becomes very dry and powdery in the ladle, the Electricity is revived no more by ſimple melting; but if then a little olive oil be added, and mixed well with the chocolate in the ladle, on pouring it into the tin pan, as at firſt, it will be found to have completely recovered its electric power *.

Now that we are ſpeaking of melted Electrics, it will not be improper to obſerve, that it ſometimes happens, that ſome electric ſubſtances, by being melted and left to cool, acquire an electrical power, which they retain for a conſiderable time, often for months together, eſpecially if they be preſerved free from dampneſs and duſt. Such effects have ſometimes induced Electricians to think, that ſome bodies are poſſeſſed of a permanent or perpetual Electricity, which is as inherent in their ſubſtance as the magnetic power of a loadſtone: in truth, however, no ſuch ſubſtance has yet been found; and although roſin, ſulphur,

* The above remark on chocolate, together with the method of reſtoring its power by means of olive oil, is a diſcovery of the late Mr. W. HENLY, F. R. S.

amber,

amber, ſilk, and ſome other Electrics, ſhew ſigns of Electricity for a conſiderable time after they have been rendered electrical, yet their power is continually diminiſhing till it quite vaniſhes. It is remarkable, however, that ſulphur, reſinous ſubſtances, bituminous ſubſtances, and ſilk, retain in general the electric power much longer than glaſs, or any other Electrics; the reaſon may be, that they do not attract moiſture like glaſs and other ſubſtances, or perhaps becauſe they are more porous.

If a ſtick of ſealing-wax be broken into two pieces, the extremities that were contiguous will be found electrified, one poſitively, and the other negatively.

The property of exhibiting electrical phænomena, by means of heating and cooling, was firſt obſerved in a hard ſemi-pellucid foſſil, known under the name of Tourmalin *. This ſtone, which is generally of

* This ſtone is called *aſchentrickker* by the Dutch, from its property of attracting the aſhes, when laid near the fire. Linnæus calls it *lapis electricus*. See his Flora Zeylonica.

a deep

a deep red or purple colour, and ſeldom exceeds the ſize of a ſmall walnut, is common in ſeveral parts of the Eaſt Indies, and eſpecially in the iſland of Ceylon. Its properties in regard to Electricity are the following:

1. The Tourmalin, while kept in the ſame degree of heat, ſhews no ſigns of Electricity, but it will become electrical by increaſing or diminiſhing its heat, and ſtronger in the latter than in the former circumſtance. An exceedingly ſmall variation of temperature is often ſufficient to render the Tourmalin ſenſibly electrical.

2. Its Electricity does not appear all over its ſurface, but only on two oppoſite ſides, which may be called its poles, and they are always in one right line with the center of the ſtone, and in the direction of its ſtrata; in which direction the ſtone is abſolutely opaque, though on the other, ſemitranſparent.

3. Whilſt the Tourmalin is heating, one of its ſides (diſtinguiſhed by A) is electri-

fied plus, and the other fide B, minus. But when it is cooling, A is minus, and B is plus *.

4. If it be heated, and fuffered to cool without either of its fides being touched, then A will appear pofitive, and B negative, all the time of its heating or cooling.

5. If this ftone be excited by friction, like any other Electric, then each of its fides, or both at once, may be made Pofitive.

6. If the Tourmalin be heated or cooled upon fome other infulated body, that body will be found electrified as well as the ftone, and poffeffed of the Electricity contrary to that, acquired by that fide of the ftone which was laid upon it.

* From this law may be eafily deduced, that if one fide of the ftone, in fome circumftance or other, is growing hot, while the other is cooling, then both fides will appear poffeffed of the fame electricity at the fame time; and if only one fide changes its degree of heat, while the other remains the fame, then the former fide only will appear electrified.

7. The

7. The Electricity of each ſide, or of both, may be reverſed by heating or cooling the Tourmalin in contact with various ſubſtances; ſo if it is cooled, or heated, in contact with the palm of the hand, that ſide of it, which would have been poſitive if cooled in the open air, is now negative; and that, which would have been negative, is now poſitive.

8. If a Tourmalin be cut into ſeveral parts, each piece will have its poſitive and negative poles, correſponding to the poſitive and negative ſides of the ſtone from which it was cut.

9. Theſe properties of the Tourmalin are alſo obſervable in vacuo, but not ſo ſtrong as in the open air.

10. If this ſtone be covered all over with ſome electric ſubſtance, as ſealing-wax, oil, &c. it will in general ſhow the ſame appearances with this coating, as without it.

11. Mr. WILLIAM CANTON obſerved a very vivid light to appear upon the Tourmalin, while heating in the dark: he can

by

by this determine, which end of the ſtone will be poſitive, and which negative. Further, when the ſtone is ſtrongly excited, it emits very ſtrong flaſhes from the poſitive to the negative end, in the dark *.

12. In the laſt place, it is remarkable that the power of the Tourmalin is ſometimes injured by the action of a ſtrong fire, ſometimes improved, and ſometimes not at all affected by it. The laws, however, of theſe uncertain effects have not yet been aſcertained.

Moſt of the above properties, which were firſt obſerved of the Tourmalin, and thought peculiar to it alone, have been found to belong to ſeveral hard precious ſtones; they being alſo made electrical by heating and cooling, and have their poſitive and negative ſides, laying in the direction of their ſtrata or cryſtals; and, in ſhort, as far as

* The Braſilian emerald, Mr. Canton has obſerved to have alſo this property of emitting light, whilſt heating in the dark: but I imagine that every other precious ſtone will ſhew it, if its electric power is ſufficiently ſtrong; ſince the light is a conſequence of the paſſage of a ſufficient quantity of electricity through the air, or other partly reſiſting medium.

has

has been obſerved, they have been found to act exactly like Tourmalins; though ſome poſſeſs this property in a much higher degree than others.

The other method of producing electricity, namely, by evaporation, &c. was lately diſcovered by Mr. Volta; and it ſeems to open the way to an ample field of ſpeculation. This ingenious philoſopher diſcovered that the evaporation of water, and of ſome other fluids, and likewiſe that ſeveral efferveſcences, generated electricity. His experiments ſeem to ſhew the generality of the following law, *viz.* that fluids, or bodies in general, when reduced in the form of vapour, become electrified poſitively, and leave the bodies, with which they were laſt in contact, electrified negatively; but on the contrary, when the vapours are condenſed in the form of a fluid, then they become electrified negatively, and leave thoſe bodies, with which they were laſtly in contact, electrified poſitively.—Farther explanations and exemplifications of this principle will be found in the practical part of this treatiſe.

We ſhall laſtly obſerve, in this chapter of excitation, that whenever an Electric is rubbed with another inſulated ſubſtance, although it requires an electric power, and ſhews electrical appearances, yet that power is very weak; and in order to obtain a conſiderable Electricity, it is neceſſary that the rubber ſhould have a regular communication with the earth, by means of good Conductors.

C H A P. V.

Of communicated Electricity.

IN the preceding chapters we have conſidered Electricity no further than in reſpect to its quality; we have remarked the differences between the Poſitive and the Negative, and have noted which bodies, and by what means, they could acquire this property.—But now a vaſt proſpect is opening to our view, full of extraordinary appearances; and we are to conſider in this chapter, not the mere kind of Electricity, but its numerous effects. Under the title of Commu-

Communicated Electricity, falls almoſt all that is known of the ſubject; the paſſage of this virtue from one body to another is what cauſes its light; by being communicated to other bodies, we ſee its attraction; by its quick tranſition it is that it melts metals, deſtroys animal and vegetable life; and, in ſhort, it is by this communication that the ſcience is at all known and cultivated. In order, therefore, to preſerve perſpicuity and diſtinction, in deſcribing ſuch a multitude of facts, I ſhall employ more chapters on this ſubject, and arrange in each ſuch particulars as ſeem moſt proper to be placed together; at the ſame time contriving to reduce the whole into as few principal heads as is poſſible, without confuſion.

Whenever Electricity is by any means ſuperinduced on a body, it is there confined only by Electrics, and remains with that body a longer or a ſhorter time, according as the Electrics that confine it are more or leſs perfect. A glaſs tube, for inſtance, when rubbed, acquires a quantity of that power, whatever it is, which we call

Electricity. That Electricity remains, and is perceivable upon the glaſs, inſomuch as it is ſurrounded by the air, which is an Electric; and as the air is in a more or leſs perfect electric ſtate, ſo that virtue is retained upon the glaſs longer or ſhorter*; and becauſe the air is never a perfect Electric, therefore the excited tube can never preſerve the acquired Electricity perpetually, but is continually imparting ſome of it to the contiguous air, or to the conducting particles that float in that element, till at laſt it quite loſes its power. If a finger, or any other Conductor, be preſented towards an excited Electric, it will receive a ſpark, and in that ſpark part only of the Electricity of the Electric; but why not all? Becauſe the excited electric, being a Non-conductor, cannot convey the Electricity of all its ſurface to that ſide, to which the Conductor has been preſented. Hence, if a conducting ſubſtance be ſucceſſively preſented to dif-

* An excited glaſs tube, if kept in a dry and rather warm place, for inſtance, at ſome diſtance from a good fire, will continue electrified above twenty hours.

ferent

ferent parts of an excited Electric, it will receive at every approach a ſpark, without repeating the excitation, till all the power of that Electric is exhauſted, and then a new excitation is neceſſary in order to revive it.

Whenever a Conductor communicating with the earth is exhibited at a convenient diſtance to an excited Electric, it acquires on that exhibited ſide an Electricity contrary to that poſſeſſed by the Electric: this Electricity increaſes the nearer it is approached, and at laſt, as there is an eager attraction between Poſitive and Negative Electricity, the Conductor receives a ſpark from the Electric, and ſo the balance is reſtored. If this Conductor do not communicate with the earth, but is inſulated, and approached to the excited Electric as before, then not only that ſide of it which is towards the Electric, but the oppoſite ſide alſo, will appear electrified; with this difference, however, that the ſide, which is expoſed to the influence of the Electric, has acquired an Electricity contrary to that of the excited Electric, and the oppoſite ſide

an Electricity of the ſame kind with that of the Electric. Theſe two different Electricities of the Conductor increaſe as it comes nearer to the Electric, and at laſt, the former receiving a ſpark from the latter, becomes throughout poſſeſſed of the ſame Electricity with the Electric from which it has received the ſpark. All theſe effects will happen in the ſame manner, if between the excited Electric and the approached Conductor there be interpoſed ſome other electric ſubſtance beſides air; as, for inſtance, a thin plate of glaſs, roſin, ſealing-wax, &c. but then a ſpark can never come from the excited Electric to the Conductor, except it forces, or burſts its way through the interpoſed Electric, as it always does through the air. This diſplacing of the air is what cauſes the noiſe that attends a ſpark, and that noiſe is more or leſs loud in proportion to the quantity of Electricity, and to the reſiſtance it meets with in its paſſage.

An inſulated Conductor having received the Electricity from an excited Electric (in which ſtate it is ſaid to be *electrified by commu-*

communication) will act in every respect like the excited Electric itself, except that, when it is touched by another Conductor communicating with the earth, the former gives one spark to the latter, and by that discharges all its Electricity. The reason why an electrified Conductor loseth its Electricity all at once, when touched with another Conductor communicating with the earth, and not part of it only, like the excited Electric, is, because the Electricity belonging to the whole of the Conductor is easily conducted through its own substance, to that side, to which the other Conductor is presented *. Hence it appears that, in general, the Electricity discharged from an electrified Conductor is much more powerful than when discharged from an Electric; for the Conductor may acquire a great quantity of Electricity from an Electric, by receiving spark after spark, and af-

* This proposition must be considered under some limitations, arising from various circumstances; for instance, if the electrified conductor is very much extended, and is touched with an imperfect conductor, or for a very short time, then it is not unlikely that some electricity will remain in it even after the spark.

terwards, if touched, will difcharge it all at once, and not by little and little as it was received.

If an infulated Conductor be touched with another Conductor electrified, it will acquire part of the Electricity belonging to the electrified Conductor, and afterwards each will fhow figns of it. The Electricity in this cafe will not always be equally divided between the two Conductors, nor will it keep any proportion to the quantity of matter in each contained; but will obferve the following laws:

1. If two infulated Conductors, that in refpect to their external furfaces and fituations are equal and fimilar, and both, or only one electrified, are touched together, the Electricity will be equally divided among them.

2. If their furfaces are equal and diffimilar, as, for inftance, a fquare foot of tin foil in one piece, and another fquare foot of it cut in a long flip, then that body, whofe

ſurface has a greater extenſion, will acquire more Electricity than the other.

3. If their ſurfaces are unequal and diſſimilar, the Electricity that each acquires after the contact, ſeems pretty clear from experiments, and in conſequence of the above two laws, to be in a compound proportion of their ſurfaces, and the extenſions of the ſame.

4. Laſtly, if one of two equal and ſimilar conductors lies with its ſurface contiguous to an imperfect conductor, and the other is only contiguous to the air, then the former will acquire a greater quantity of Electricity than the latter. But this property is ſubject to certain limitations, which, to prevent confuſion, will be mentioned in the practical part.

The electric ſpark (*i. e.* a ſeparate quantity of Electricity) will go a greater or leſs diſtance through the air, in order to reach a Conductor, according as its quantity is greater or leſs; as the parts from which it

flies

flies off, and on which it ſtrikes, are more ſharp or more blunt, and as the Conductor is more or leſs perfect. The noiſe together, and the light with which the ſpark is attended, is greater or leſs, according as the Electricity is greater or leſs; as the parts from which it flies, and on which it ſtrikes, are more blunt or more ſharp; and as the Conductor is more or leſs perfect. Thus, for inſtance, a ſharp-pointed body will throw off Electricity to, and receive it from, a greater diſtance, than a body of any other ſhape; but then that paſſage occaſions no noiſe, and is attended with little light; for, in this caſe, the Electricity does not come in a ſeparate large body, but by little and little, or rather by a continued ſtream. If a pointed wire be concealed in a glaſs tube, which projects a ſhort way beyond it, or if it be covered with tallow, bees-wax, ſulphur, &c. then it will take a ſtrong ſpark from an electrified Conductor.

It is remarkable, in the caſe of points throwing off or receiving Electricity, that a current of air is ſenſible at an electrified point,

point, which is always in the direction of the point, whether the Electricity is positive or negative.

The electric ſpark, taken upon any part of a living animal body, cauſeth a diſagreeable ſenſation, which is more or leſs troubleſome, as the ſpark is ſtronger or weaker, and the part, upon which it is taken, is more or leſs delicate; and alſo according to the particular conſtitution of individuals.

A pretty large quantity of Electricity pervades the ſubſtance of a Conductor of a conſiderable length, with a ſurpriſing and imperceptible velocity; but a ſmall quantity of it has been found to take ſome little time in paſſing through a long, and leſs perfect, Conductor.

Bodies poſſeſſed of the ſame Electricity, whether poſitive or negative, repel each other. But bodies poſſeſſed of different Electricities, attract each other; and there is no electric repulſion, but between bodies poſſeſſed of the ſame Electricity; nor electric attraction,

attraction, but between bodies possessed of different Electricities, *i. e.* between bodies positively and bodies negatively electrified *.

Electricity, strongly communicated to insulated animal bodies, quickens their pulse, and promotes their perspiration. If it be communicated to insulated fruits, fluids, and in general to every kind of bodies that are actually in a state of evaporation, it also increases that evaporation; and that in a greater or less degree, as those bodies are more or less subject to evaporate of themselves; as the vessels, that contain the same, are Conductors or Electrics; and as they

* This law, *i. e.* that there is no electric attraction, except between bodies possessed of different Electricities, will, perhaps, appear paradoxical, upon observing, that an excited Electric attracts small bodies, which never were by any means made electrical before; but the paradox will soon vanish, if what has been said above be considered, *i. e.* that when Conductors, and indeed Electrics too, come near an electrified body, they become actually possessed of a different Electricity. But this will appear much clearer from the experiments that are to be mentioned hereafter.

have

have a greater or leſs ſurface expoſed to the open air *.

By increaſing the perſpiration of vegetables, Electricity promotes their growth; it having been found, after ſeveral accurate experiments, that ſuch plants, which have been often and long electrified, have ſhewed a more lively and forward appearance, than others of the ſame kind that were not electrified †.

When Electricity is communicated to inſulated veſſels, containing water that is actually running from a pipe, the effects will, as far as may in groſs be deduced from experiments, obſerve the following laws:

* Although it has been by ſome pretended, that Electricity cauſed ſeveral ſubſtances to evaporate through the pores of glaſs and metals, yet that could never be obſerved, though many accurate experiments were made for that purpoſe: beſides, this pretended evaporation ſeems on all accounts exceedingly improbable.

† It is ſaid by Mr. KOESTLIN to have been found, that negative electrization retards both animal and vegetable life.—See his Latin Diſſertation on the effects of Electricity upon ſome organic bodies.

"1. The

"1. The electrified stream, though it "divides, and carries the liquid further, is "neither sensibly accelerated nor retarded, "when the pipe through which it issues is "not less than a line in diameter.

"2. Under this diameter, if the tube is "wide enough to let the liquid run in a "continued stream, Electricity accelerates "it a little, but less than a person would "imagine, if he judged by the numbers of "jets which are formed, and by the dis-"tance to which they go.

"3. If the tube be a capillary one, from "which the water only drops naturally, "the electrified jet not only becomes a "continued stream, and even divided into "several streams, but is also considerably "accelerated; and the smaller the capil-"lary tube is, the greater, in proportion, "is the acceleration.

"4. So great is the effect of the electric "virtue, that it drives the water in a con-"stant stream out of a very small capillary "tube, out of which it had not before been "able even to drop."

§ The

The electric power has been found not to be affected by, or to affect, the magnetic virtue of a loadſtone; neither is it affected by heat or cold; ſince an iron bar made red-hot, or any conducting ſubſtance hard frozen, when electrified, attracts, repels, gives ſparks, &c. nearly in the ſame manner as in its natural temperature. Electric attraction is obſervable alſo in vacuo, and electric ſubſtances may alſo be excited in the vacuum of an air-pump; but both in a degree decreaſing in proportion to the rarefaction *.

Laſtly, we ſhall conclude this chapter with remarking, that if the face, or any part of the body, be preſented to an excited Electric, or to a Conductor ſtrongly electrified, it will feel as if a wind was blowing, or rather as if a ſpider's web was drawn over it; alſo, if the noſtrils are preſented to an excited Electric, they will be affected by a ſmell, much reſembling

* This has been lately inveſtigated by ſeveral new experiments, for which ſee the laſt part of this work.

that

that of phoſphorus; but communicated Electricity does not occaſion any ſuch ſenſation, except when a large quantity of it does ſuddenly paſs from one body to another. If bodies are kept for ſome time within the electric effluvia when ſtrong, they will retain the ſmell that they acquire for a conſiderable time after.

CHAP. VI.

Of Electricity communicated to Electrics.

AS the Electric virtue can be ſuperinduced on Conductors by communication, ſo may it alſo be communicated to Electrics: the difference however is, as might be expected, very remarkable; for when one ſide of a Conductor is preſented to an electrified body, the Electricity will inſtantly pervade its whole ſubſtance, on account of its conducting nature; whereas, when an Electric is preſented to another Electric excited, or to an electrified Conductor, it will with ſome difficulty acquire

any Electricity, becauſe its ſubſtance is impervious to that virtue; and in order to make it acquire ſome, it muſt be ſeveral times, and in different parts, touched with the electrified body. That it is as difficult to deprive an Electric of its acquired Electricity, as it is to ſuperinduce it on its ſurface, I think might eaſily be ſuppoſed; for the very ſame quality, which cauſeth it to acquire that power ſlowly (namely its being a Non-conductor) makes it alſo part with it ſlowly; and, in order abſolutely to deprive the Electric of its acquired Electricity, it muſt be touched ſeveral times, and in almoſt every part of its ſurface, with ſome conducting ſubſtance.

In the preceding chapter we obſerved, that when an inſulated Conductor is preſented to an electrified body, it acquires, on the part neareſt to that body, a contrary Electricity; and on the oppoſite part, an Electricity of the ſame kind with that of the electrified body; we alſo obſerved, that theſe two Electricities increaſe, as the Conductor comes near to the electrified body, and that when the Conductor is ar-

rived within the ſtriking diſtance of that body, a quantity of Electricity flies off from the latter; forces its way through the intermediate air; and, ſtriking upon the former, renders it throughout poſſeſſed of the ſame Electricity. Theſe effects are in a certain degree alſo obſervable, when an Electric, inſtead of a Conductor, is preſented to an electrified body; for the Electric will alſo acquire, on different ſides, contrary Electricities: theſe Electricities increaſe, as the diſtance decreaſes; but if at laſt a ſmall quantity of Electricity is communicated to one part of the Electric, that Electric will not become throughout poſſeſſed of one Electricity, but will ſtill, in ſome caſes, ſhew different Electricities on different ſides; and in ſome circumſtances, many repeated changes from poſitive to negative Electricity may be obſerved upon the ſame Electric, as will appear from the following experiment; which, however, though mentioned by ſome very reſpectable philoſophers and electricians, yet I muſt confeſs that it ſucceeds very ſeldom, if ever, clearly.

If

If the end of a pretty long glaſs tube be preſented to a body electrified, for inſtance poſitively, the tube will be found electrified poſitively alſo for the ſpace of one or two inches at that end; but, beyond that ſpace, will be found two or three inches electrified negatively; after that, another poſitive Electricity will appear; and ſo, alternately, a poſitive and a negative zone will follow one another, always weaker and weaker in power, till at laſt they quite vaniſh *. Now the cauſe of theſe effects is always to be deduced from the two above-mentioned principles, *i. e.* the non-conducting quality of an Electric, and the properties of bodies in general to acquire an Electricity contrary to that poſſeſſed by another contiguous electrified body: ſo, in the above experiment, that end of the tube which was preſented to the body electrified poſitively, before it received any Electricity from that body, appeared negative on the part preſented to it; but, after it had received ſome Electricity, ap-

* See PRIESTLEY's Hiſt. of Elect. Per. X. Sect. v. and Æpini Tentamen, p. 192.

peared to be positive no further than that Electricity could be spread over its surface; but beyond that place a part of the tube appeared to be negative, on account of its contiguity to the part electrified positively; after that, another place appeared to be positive, because of its contiguity to the part electrified negatively, and so of the subsequent changes; and the positive Electricity of one part of the tube cannot mix with the adjoining negative part, so as to prevent these appearances, because the non-conducting quality of the glass will always hinder such an effect from taking place.

If to one side of an Electric sufficiently thin, as for instance a pane of common window-glass, a plate of sealing-wax, &c. be communicated one Electricity, and to the opposite side be communicated the contrary, that plate in that case is said to be *charged*, and the two Electricities can never come together, except a communication of conducting substances be made between both sides, or the Electric be broken by the power of electric attraction. When the two Electricities of a charged Electric are

are by any means united, and therefore their power deſtroyed, that Electric is then ſaid to be *diſcharged*, and the act of union of theſe two oppoſite powers is, for a reaſon hereafter to be mentioned, called the *electric Shock*.

In order to avoid the difficulty of communicating Electricity to an electric plate, it is cuſtomary to coat the ſides of it with ſome conducting ſubſtance, as tin-foil, gilt paper, &c. by which means the charging and diſcharging becomes very eaſy; for when the Electricity is communicated to one part of the coating, it is immediately ſpread through all the parts of the Electric that are in contact with that coating; and when the Electric is to be diſcharged, it is ſufficient to make a conducting communication between the coatings of both ſides, in order to diſcharge entirely the Electricities of that Electric.

It will be readily underſtood why the coatings of both ſides of an Electric ſhould not come very near one another towards the edge of the plate, for then a communica-

tion between the ſame coatings is ready at hand; and although they do not abſolutely touch one another, yet, when they are electrified, the Electricity will eaſily force a paſſage through the air, and, by paſſing over the ſurface of the Electric from one coating to the other, renders it incapable of receiving any charge *.

By means of charged Electrics, we may ſee a diſplay of the greateſt powers of Electricity; we can accumulate this power, and uſe it advantageouſly in different experiments. By conſidering the properties of a charged Electric, we become further and better acquainted with this ſcience, than by any other means; and for the enumeration of theſe properties the following chapter is employed.

* The property of conducting the Electricity over their ſurface is ſo remarkable in ſome kinds of glaſs, that they are on this account abſolutely unfit for the purpoſe of charging and diſcharging.

CHAP.

CHAP. VII.

Of charged Electrics, or the Leyden Phial.

IF a glaſs plate, whether ſmooth or rough, be coated with ſome conducting ſubſtance on both ſides, ſo that the coatings do not come ſo very near the edge of the glaſs, as to render it unfit to be charged, and if to one of thoſe coatings be communicated ſome Electricity, the other coating, while communicating with the earth, or with a ſufficient quantity of conducting bodies, acquires by itſelf an equal quantity of the contrary Electricity; but if, whilſt one ſide is acquiring Electricity, the oppoſite ſide does not communicate with the earth, or with a ſufficient quantity of conducting ſubſtances, the glaſs cannot be charged*. Now the reaſon why, when one ſide of the glaſs is receiving one Electricity, the oppoſite ſide acquires the other, is the

* Strictly ſpeaking, the glaſs in this caſe will be charged a little, becauſe the air which is contiguous to its coating is not a perfect Non-conductor.

ſame as obſerved in the preceding chapter, *i. e.* the property of bodies to acquire an Electricity contrary to that poſſeſſed by a contiguous electrified body; and the cauſe, that hinders theſe two Electricities from mixing together, is the interpoſition of the glaſs plate, which is impermeable to Electricity *; but if the charge is too high, and the glaſs plate too thin, then the great attraction between the two different Electricities, forces a paſſage through the glaſs, diſcharges it, and renders it unfit to receive another charge.

Theſe effects happen in the ſame manner if the glaſs be not in the form of a plate,

* This remarkable property of Electricity was firſt ſatisfactorily obſerved (though not originally diſcovered, as we have already taken notice of in the Introduction) at Leyden, with a bottle containing ſome water, which ſerved for the inſide coating, and the undeſigned application of the hands on the outſide ſerved for another coating. A bottle coated on the inſide and outſide for the purpoſe of being charged, has from thence been called the *Leyden Phial*, otherwiſe an *electric Jar*; and the charging and diſcharging, in general, of coated glaſs, has been called the *Leyden Experiment.*

but

but in any other ſhape whatſoever, provided it be ſufficiently thin; it being not the form, but the thickneſs of the glaſs, that makes it more or leſs fit to be charged: and the thinner it is, the greater charge it is capable of receiving; for the ſtronger in proportion is the power of the Electricity of one ſide, to cauſe a contrary Electricity on the oppoſite ſide.

How thick a glaſs plate or other Electric ſhould be, to become incapable of being charged, hath not yet been aſcertained.

A coated glaſs is capable of holding a greater charge in condenſed than in rarefied air, or even than when charged under the uſual preſſure of the atmoſphere.

If a coated glaſs plate, or phial, after being charged, be inſulated, and only one of its ſides be touched with ſome Conductor, that ſide will not part with its Electricity, becauſe the Electricity of one ſide exiſts in conſequence of the contrary Electricity on the oppoſite ſide, and both, by their mutual attraction, confine one another

another upon the ſurface of the glaſs. In order therefore to diſcharge that glaſs, both its coatings muſt be touched at the ſame time, and connected with the earth: or by means of ſome Conductor a communication muſt be made between them; and in this caſe the diſcharge is ſaid to be made through that Conductor.

When, in order to diſcharge a jar, one of its coatings is touched firſt with a Conductor, as, for inſtance, with one end of a chain, nothing very particular in that caſe will appear*; but as ſoon as the other end of the chain comes within a ſufficient diſtance of the other coating, a ſpark will be ſeen between the end of the chain and that coating, accompanied with a noiſe, &c. juſt as when an excited Electric, or an electrified Conductor, is made to communicate with another Conductor; but the power,

* If one coating of a charged jar communicates with the earth, while the other coating is expoſed to the free air for ſome time, the charge of that jar will be ſilently and gradually diſſipated; for while the Electricity of one ſide goes to the earth, the Electricity of the other is communicated to the air, which, as we obſerved before, is never a perfect Electric.

the

the light, and the report is in general much greater than that of a ſpark taken from a body ſimply electrified.

If the communication between the two ſides of a charged jar be made by imperfect Conductors, as a ſlender piece of wood, a wet packthread, &c. the diſcharge will be made ſilently and without exploſion.

It is remarkable, that the ſpark occaſioned by the diſcharge of charged Electrics, although it is more denſe, more powerful, and makes a greater report, yet is not ſo long as the ſpark drawn from an electrified Conductor.

When the diſcharge of a jar is made through the body of a living animal, it occaſions a ſudden motion, by contracting the muſcles through which it paſſes, and gives a diſagreeable ſenſation; for which reaſon, the effect of diſcharging an electric jar has been generally called the *electric Shock*. This ſhock is more ſenſibly felt by ſome peaſons than by others, and it is ſaid that ſome are not at all affected by it.

The

The force of the electric ſhock, occaſioned by glaſſes of the ſame thickneſs, is greater or leſs in proportion to the quantity of coated ſurface, and the height of the charge. Upon this principle, the power of the ſaid ſhock, by increaſing the quantity of coated glaſs, may be augmented at pleaſure, provided means be uſed powerful enough to charge it.

A number of coated jars connected together in ſuch manner that their whole force may be united, and act like one jar, conſtitutes what is called an *electrical Battery*. This battery is the moſt formidable and entertaining part of an electrical apparatus, and by its uſe many wonderful effects are produced:—but as the performing of theſe belongs rather to the practical, than to the preſent part of this Treatiſe, I ſhall only enumerate them in this place, and reſerve further particulars for the third part of this work.

In making the diſcharge of an electric jar, it is ſurpriſing to obſerve with what quickneſs the Electricity performs the cir-

cuit

cuit from one ſide of the glaſs to the other. It has been found to employ no perceivable time in going through a Conductor of ſeveral miles, which connected the two coatings of a phial *.

The force and noiſe of an electric ſhock is not affected by the inflections of the Conductor, through which it goes, but it is ſenſibly weakened by its length; hence, when the circuit, *i. e.* the communication between the two ſides of the electric phial, is made by one perſon touching one ſide with one hand, and the oppoſite ſide with the other, the ſhock is ſtronger than when the circuit is formed by many perſons together joining hands.

That the Electricity finds ſome obſtruction in going through even the beſt Conductors, appears evident from this, that in ſome caſes it will prefer a ſhort paſſage through the air, to a long one through Conductors, even the moſt perfect. This obſtruction is greater in thoſe places, where the Conductors, forming the circuit, do not

* PRIESTLEY's Hiſt. of Elect. Per. VIII. Sect. ii.

lie

lie in perfect contact; and if, the circuit being composed of Conductors of different natures, the Electricity be obliged to pass from one Conductor to another less perfect, the obstruction is still greater. If a small interruption of the circuit be made in water, on making the discharge (notwithstanding that the water is a Conductor) a spark will be seen in it, which never fails to agitate the water, and often breaks the vessel that contains it.

A strong shock, sent through an animal or a plant, puts an end to animal as well as to vegetable life. If the circuit be interrupted by one or more Electrics, or imperfect Conductors, of a moderate thickness, the electric shock will break them, and in some circumstances disperse them in every direction, and in such manner as if the force proceeded from the center of every one of the interposed bodies *.

* In several instances the effect of a shock upon an interposed body is evidently greater on that side of it which communicates with that coating of the jar or battery, that is possessed of the positive Electricity. But of this more will be said hereafter.

A strong

A ſtrong ſhock, ſent through a ſlender piece of metal, makes it inſtantly red-hot, melts it, and, if the fuſion is perfect, reduces it into globules of different magnitudes. If the metal be incloſed between pieces of glaſs, the ſhock, by melting it, will force it into the ſubſtance of the glaſs, ſo that afterwards it cannot be taken off without ſcraping part of the glaſs with it. In this experiment the glaſſes are ſhattered to pieces, and it is ſeldom that they reſiſt the force of a ſtrong ſhock.

If the glaſſes, incloſing the metal, be preſſed by heavy weights, then a remarkable ſmall ſhock is capable often not only to raiſe the weight, but to break ſuch thick glaſſes, that otherwiſe require the force of a large battery. Thick pieces of glaſs may be alſo broken into innumerable fragments, by only ſending a ſhock over a ſmall part of their ſurface, which is preſſed by weights, without the interpoſition of any metal. When theſe pieces of glaſs are not broken, they are marked by the exploſion with the moſt lively priſmatic colours, which lie ſometimes confuſed, and ſome-

times in their priſmatic order. The colour-ed ſpot is evidently formed by thin plates or ſcales, in part ſeparated from the ſurface of the glaſs; and it generally occupies the ſpace of about one inch in length, and half an inch in breadth.

In melting wires of the ſame metal by the electric ſhock, it muſt be obſerved, that the forces required for that purpoſe muſt be greater or leſs, according as the lengths or thickneſſes of the wires are greater or leſs: but they are far from bearing any direct proportion to the quantity of metal; for if a wire of a given length and diameter be barely melted by a large battery, a wire of equal length, and twice the ſubſtance, would perhaps take ten ſuch batteries to produce the ſame effect upon it.

When a moderate ſhock * is ſent through an imperfect metal (eſpecially if the circuit be formed by ſeveral pieces, as by a chain), a black duſt, in the form of ſmoke, will be

* By a moderate ſhock here, I mean, one that is not able to melt the metal through which it paſſes.

ſeen

ſeen to proceed from the metal, which is thought to be ſome of the metal itſelf partly calcined, and, by the violence of the exploſion, forced from it.

If ſuch circuit, or part of it, be laid upon a piece of paper, glaſs, or other Non-conductor, this, after the exploſion, will be found ſtained with ſome indelible marks, and often ſhew evident ſigns of having been burnt. A long and permanent track may be marked upon glaſs, and ſome other bodies, by the electric exploſion, if the interruption of the circuit be made upon its ſurface.

What is more remarkable, in conſidering the effects of Electricity on metals, is, that it revivifies their calces; and, like a true phlogiſtic proceſs, when an exploſion is made through a piece of the ſame, it in part returns into its metalline form. But here one might juſtly ſuſpect that the phlogiſton neceſſary to revivify the calx is forced out of other bodies that contain it, and which lie in the circuit.

Although we obſerved, in the fifth chapter, that Electricity and Magnetiſm did not interfere with one another's action, yet that muſt not be underſtood in general, and when a large force of Electricity is meant; for this is capable not only of deſtroying the virtue, or of reverſing the poles of a magnetic needle, but even of giving it that virtue. When the charge of ten, eight, and even a leſs number of ſquare feet of coated glaſs is ſent through a fine ſewing-needle, it will often give it polarity, ſo that it will traverſe when laid on water*. It is remarkable, that if the needle be ſtruck, lying eaſt and weſt, that end of it which is entered by the ſhock, viz. that end which communicates with the poſitive ſide of the battery, or jar, will afterwards point north; but if the needle be ſtruck, lying north and ſouth, that end of it which lay towards the north, will in any caſe point north; and the needle will acquire a ſtronger virtue in this, than in the

* A ſmart ſtroke of a hammer will make a needle magnetic: but they ſhould always be tried before the experiment; for many ſmall needles will traverſe upon water, without the electric ſhock, or the ſtroke of the hammer.

former caſe. Laſtly, if the needle is ſet perpendicular to the horizon, and the electric ſhock is given to either point of it, afterwards the lower extremity of the needle will point north *.

That the electric ſpark ſhould kindle inflammable ſubſtances, I think might be expected, when its power has been conſidered in many circumſtances, in which it has been obſerved to act as a moſt penetrating and extraordinary fire. In firing ſeveral ſubſtances, a ſmall ſhock is ſufficient; and inflammable ſpirits may be fired even by a ſpark proceeding from an electrified Conductor.

If the moderate charge of a large battery be diſcharged between two ſmooth ſurfaces of metals, or ſemi-metals, lying at a ſmall diſtance from each other, a beautiful ſpot will be marked upon them. This conſiſts of one central ſpot, and ſome concentric

* See Dr. FRANKLIN's Letters, p. 90; and BECCARIA's Artificial Electricity, § 731, 732, 733, 734.

circles *, which are more or leſs diſtinct, and more or leſs in number, according as the metal upon which they are marked, requires a leſs or greater degree of heat to be melted, and as a greater or leſs force is employed.

If the exploſion of a battery, iſſuing from a pointed body, as the point of a needle, be repeatedly taken upon the plain ſurface of a piece of metal ſituated at a little diſtance from the point, or if iſſuing from the ſurface, be taken upon the point, that metal will be marked with a coloured ſpot, conſiſting of all the priſmatic colours diſpoſed in circles, and evidently formed by ſcales, or thin plates of the metal ſeparated by the force of the exploſion †.

When the diſcharge of a battery is made by bringing the ends of two Conductors, communicating with the inſide and the outſide of the battery, in contact with, or

* The central ſpot as well as the circles lie at a little diſtance from one another; and they are compoſed of dots and cavities, indicating a true fuſion.

† For further particulars concerning thoſe circles, ſee the Phil. Tranſ. vol. LVIII.

at

at a little diſtance from, the ſurface of ſeveral conducting ſubſtances, as water, raw meat, &c. it is obſervable that the Electricity, inſtead of entering thoſe ſubſtances, goes over their ſurface, and in a lucid ſeparate body reaches from Conductor to Conductor; ſometimes it prefers a much longer paſſage over the ſurface, to a ſhorter one through any ſubſtance. In this caſe the exploſion never fails to give a concuſſion to the body, over whoſe ſurface it paſſes.

The electric exploſion, or even electric ſparks, when taken in different kinds of air, or permanently elaſtic fluid, was obſerved by Dr. PRIESTLEY to act like a true phlogiſtic proceſs*. But, upon a nicer examination, it ſeems that the phlogiſtic principle does not proceed from the electric fluid itſelf, but is detached, by the force of Electricity, from thoſe Conductors, between which the exploſions or ſparks are taken †. It may be alſo mentioned in this place to have been

* See Dr. PRIESTLEY's ſecond vol. of Obſervations on different Kinds of Air.

† See my Treatiſe on Air, and other permanently elaſtic fluids, p. 433.

found by Dr. PRIESTLEY, that every kind of permanently elaſtic fluid is a Non-conductor of Electricity; but probably they are not all of the ſame degree. The colour of the electric ſpark, although equally viſible, yet is not of the ſame colour in every ſort of elaſtic fluid. In inflammable and in alkaline air, it appears of a purple or red colour; in fixed air it appears white.

The electric exploſions taken upon the leaves of certain flowers, change their colour *.

Beſides the above-mentioned properties of charged glaſs, there are a few more obſerved, which as yet have neither been ſufficiently inveſtigated, nor ſo far purſued as to be reduced under any general laws. They afford a great field for ſpeculation, and ſeem to be more intimately connected with the nature of Electrics in general; but it ſeems not proper to make any general concluſions from the facts already known, at leaſt ſo as

* Dr. PRIESTLEY's Hiſt. of Electricity, Per. VII.

to

to be inſerted in this part of the preſent treatiſe. I ſhall therefore employ a chapter for the narration of the ſame, in which I ſhall relate the principal, and more promiſing experiments hitherto made, and take notice of the beſt conjectures offered for their explanation. This chapter will be found at the end of the third part, in which place, I think, it will be more acceptable to my readers, particularly ſuch as have not been much converſant with Electricity, and therefore require firſt the deſcription of the electrical apparatus, and the knowledge of the experiments neceſſary to prove the facts recited.

CHAP. VIII.

Of Atmoſpherical Electricity.

WHOEVER has remarked the numerous properties of Electricity already mentioned, and has conſidered their extenſive power, will, I doubt not, be greatly ſurpriſed, when he compares the ſtate, in which the ſcience remained half a

century ago, with that in which it is at present; but his wonder will ſtill increaſe, when he is told that Electricity is not only to be obſerved by rubbing an Electric, or warming a Tourmalin, but that it has been found to exiſt in the air, rain, and clouds: that thunder and lightning have been diſcovered to be its effects; and that, in ſhort, whatever has the appearance of fire, or of any thing extraordinary in the atmoſphere, and upon the earth, has been attributed to Electricity.

That effects of Electricity bore a great reſemblance to thunder and lightning, had been ſeveral times remarked by philoſophers, and eſpecially by the learned Abbé NOLLET; but that they ſhould actually be found to be effects of the ſame cauſe, and that the phenomena of Electricity ſhould be imitated by lightning, or thoſe of lightning by Electricity, was neither thought poſſible, nor ſuſpected, till the celebrated Dr. FRANKLIN made the bold aſſertion; and the French philoſophers firſt, and afterwards Dr. FRANKLIN, proved the fact by undeniable arguments in the year 1752.

The

The ſimilarity of lightning and Electricity is not to be remarked in a few appearances only, but it is obſervable throughout all their numerous effects, and there is not a ſingle phenomenon of the one, but may be imitated by the other. Lightning deſtroys edifices, animals, trees, &c.; lightning goes through the beſt Conductors which it meets in its way, and, if its paſſage is obſtructed by Electrics, or leſs perfect Conductors, it rends them, and diſperſes them in every direction; lightning burns, and melts metals and other ſubſtances; a ſtroke of lightning often diſturbs the virtue of a magnet, and gives polarity to ferruginous ſubſtances; and all theſe effects, as has been obſerved above, may be produced by Electricity. But, independent of the great ſimilarity exiſting between lightning and Electricity, what fully proves their identity is, that the matter of lightning may be actually brought down from the clouds by means of inſulated and pointed metallic rods, or by electrical kites, and with it any known electrical experiment may be performed.

Clouds,

Clouds, as well as rain, ſnow, and hail, that fall from them, are almoſt always electrified, but oftener negatively than poſitively; and the lightning, accompanied with the thunder, is the effect of the Electricity, which, darting from a cloud, or a number of clouds, highly electrified, ſtrikes into another cloud, or elſe upon the earth; in which caſe it prefers the moſt lofty and pointed places, and by this ſtroke produces all thoſe dreadful effects, that are known to be occaſioned by lightning.

The air, at ſome diſtance from houſes, trees, maſts of ſhips, &c. is generally electrified poſitively, particularly in froſty, clear, or foggy weather; but how the air, the fogs, and the clouds become electrified, has not yet been clearly aſcertained, although ſeveral conjectures have been offered; excepting however the principle of the electricity produced by evaporation and condenſation, which will be conſidered in the ſequel.

After that Electricity, and the matter of lightning were found to be the ſame thing,

philoſophers began to ſuſpect the action of Electricity where it had before been leſs imagined, and not without reaſon endeavoured to reconcile to it ſeveral other natural appearances. The aurora borealis, or northern light, was ſoon attributed to Electricity, on obſerving that by this that flaming light may be imitated *, and that the aurora borealis, when very ſtrong, has been known to diſturb the magnetic needle †, which is alſo an effect of Electricity.

The accenſions, that are often ſeen in the atmoſphere (commonly called *falling Stars*) are thought to be electrical appearances. The ſame is alſo ſuppoſed to be the cauſe of ſuch other meteors, like white clouds, that often appear by night-time, particularly in hot climates. Beſides theſe phenomena, water-ſpouts, hurricanes, whirlwinds, and even earthquakes, have been

* The late Mr. CANTON frequently collected Electricity in a conſiderable degree, during the time of an aurora borealis. His apparatus for that purpoſe conſiſted of an inſulated fiſhing rod, erected on the top of his houſe, and having a wire twiſted round.

† See the Phil. Tranſ. vol. LIX. page 88.

attributed

attributed to Electricity. But now, perhaps, the reader will think philosophers too extravagant, in going so far with Electricity. Such thoughts seem at first sight to be extravagancies; but if it be considered, that they do not appear to contradict the known laws of nature, that they are not assertions absolutely void of proofs, and that they are the thoughts of great philosophers, then, I think, they may be admitted, at least so far as to be tried on proper occasions, and to be considered as the most plausible conjectures yet offered in explanation of the most surprising phenomena of nature *.

* For further conjectures, see Dr. FRANKLIN'S Letters, and Dr. PRIESTLEY'S Hist. of Elect.

CHAP.

CHAP. IX.

Advantages derived from Electricity.

NATURE, ever wiſe and admirable in her actions, ſeems to follow a certain ſimilarity in her works with a conformity of operations, and, from the ſimpleſt to the moſt complicated of her objects, an analogy is obſervable, which, as it is wonderful to be conſidered, ſo it is inſtructive and uſeful. It is on account of this analogy, that whenever a diſcovery is made in any part of natural philoſophy; whenever a ſcience is advanced, we not only attain to the knowledge of that ſingle law, or particular ſcience, but at the ſame time acquire means in general of inveſtigating the operations of nature with ſomewhat more certainty and accuracy; and by purſuing that analogy we are enabled to make further diſcoveries, and to improve every branch of knowledge. How far Electricity has contributed towards this purpoſe, I think is unneceſſary to be further proved, when its

action has been ſhown to be ſo general, and ſo powerful, as to perform what no art can operate. But, beſides the field that Electricity has opened for further diſcoveries, and the ſatisfaction of that curioſity, which before attended the contemplation of ſo many wonderful phenomena as have been explained by this ſcience, there are two great advantages derived from Electricity; the one is a defence againſt the direful effects of lightning, and the other a remedy for many diſorders incident to the human body.

In order to guard edifices or ſhips from being damaged by lightning, it was judiciouſly propoſed by Dr. FRANKLIN, to raiſe a metallic Conductor ſome feet above the higheſt part of the building, and continue it down the wall till it penetrated ſome feet into the ground; by this means the houſe could never receive any damage; for whenever the lightning ſhould happen to fall upon it, it is evident that the Conductor, being of metal, and higher than any part of the building, would certainly attract it, and, by conducting it to the ground, hinder that building from receiving any damage;

it

it being well known that Electricity always ſtrikes the neareſt and beſt Conductors that it meets with in its way.

The reaſonableneſs and truth of this aſſertion has been confirmed by numberleſs facts, and the practice of raiſing ſuch Conductors has been found exceedingly uſeful, particularly in hot climates, where thunder-ſtorms are very frequent, and the damages occaſioned by the ſame too often experienced.

In regard to the conſtruction of ſuch Conductors, there have been ſome controverſies among Electricians; and the moſt advantageous manner of uſing them has not, without a great many experiments, and but very lately, been aſcertained. Some philoſophers have aſſerted that ſuch Conductors ſhould terminate in a blunt end, that they might the leſs invite the lightning from the clouds; for a blunt end will not attract Electricity from ſo great a diſtance as a ſharp point. But other philoſophers have thought a pointed termination to be much preferable to a blunt one; and their aſſertion ſeems, on the following

lowing accounts, founded on much better reasoning.

A sharp-pointed Conductor, it is true, will attract Electricity from a greater distance than a blunt one, but at the same time will attract and conduct it by little and little, or rather by a continued stream, in which manner a remarkably small Conductor is capable of conducting a very great quantity of Electricity; whereas a blunt-terminated Conductor attracts the Electricity in a full separate body, or explosion, in which manner it is often made red-hot, melted, and even exploded in smoke, and by such a quantity of Electricity as perhaps would not have at all affected it, if it had been sharply pointed.

A sharp-pointed Conductor certainly invites the matter of lightning easier than a blunt one; but to invite, receive, and conduct it in small quantities, never endangers the Conductor: and the object of fixing a Conductor to a house, is to protect the house from the effects of, and not the Conductor from transmitting the lightning.

It

It is an obſervation much in favour of ſharp-pointed Conductors, that ſuch ſteeples of churches, and edifices in general, as are terminated by pointed metallic ornaments, have very ſeldom been known to be ſtruck by lightning; whereas others that have flat or blunt terminations, and have a great quantity of metal in a manner inſulated on their tops, are often ſtruck by it, and it is but ſeldom that they eſcape without great damage. However, it happened not long ago, that a building furniſhed with many ſharp conductors was ſtruck by lightning *.

Beſides thoſe conſiderations, a ſharp-pointed Conductor, by the ſame property of attracting Electricity more than a blunt one, may actually prevent a ſtroke of lightning †, to do which a blunt-ended one is abſolutely incapable.

A Conductor therefore to guard a building, as it is now commonly uſed in con-

* See the Phil. Tranſ. Vol. LXXII.

† This and other properties of pointed Conductors will be made to appear very evidently by experiments.

ſequence of ſeveral conſiderations, and experiments, ſhould conſiſt of one iron rod * about three quarters of an inch thick, faſtened to the wall of the building, not by iron cramps, but by wooden ones. If this Conductor were quite detached from the building, and ſupported by wooden poſts at the diſtance of one or two feet from the wall, it would be much better for common edifices, but it is more particularly adviſable for powder-magazines, powder-mills, and all ſuch buildings as contain combuſtibles ready to take fire. The upper end of the Conductor ſhould be terminated in a pyramidal form, with the edges, as well as the point, very ſharp; and if the Conductor be of iron, it ſhould be gilt, or painted, for the length of one or two feet. This ſharp end ſhould be elevated above the higheſt part of the building (as above a ſtack of chimnies, to which it may be faſtened) at leaſt five or ſix feet. The

* Copper would do much better than iron for a Conductor; it being a more perfect Conductor of Electricity, and at the ſame time not being ſubject to contract ruſt ſo ſoon as iron.

lower

lower end of the Conductor ſhould be driven five or ſix feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the neareſt piece of water, if any be at hand. If this Conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care ſhould be taken, that where the pieces meet, they be made to come in as perfect a contact with one another as poſſible; for, as we obſerved before, Electricity finds conſiderable obſtruction where the Conductor is interrupted.

For an edifice of a moderate ſize, one Conductor, in the manner already deſcribed, is perhaps ſufficient; but, in order to ſecure a large building from ſuſtaining any damage by lightning, there ſhould be two, three, or more Conductors, in proportion to the extent of the building.

In ſhips a chain has often been uſed for this purpoſe, which, on account of its pliableneſs, has been found very conve-

nient, and eaſy to be managed among the rigging of the veſſel; but as the Electricity finds a great obſtruction in going through the ſeveral links, for which reaſon chains have been actually broken by the lightning, ſo their uſe has now been almoſt entirely laid aſide; and, in their ſtead, copper wires a little thicker than a gooſe-quill have been ſubſtituted, and found to anſwer very well. One of theſe wires ſhould be elevated two or three feet above the higheſt maſt in the veſſel; this ſhould be continued down the maſt, as far as the deck, where, by bending, it ſhould be adapted to the ſurface of ſuch parts, over which it may moſt conveniently be placed, and, by continuing it down the ſide of the veſſel, it ſhould be always made to communicate with the water of the ſea.

In regard to perſonal ſecurity, in caſe a thunder-ſtorm were to happen while a perſon is in a houſe not furniſhed with a proper Conductor, it is adviſable not to ſtand near places where there is any metal, as chimnies, gilt frames, iron caſements, or

or the like; but to go into the middle of a room, and endeavour to ſtand or ſit upon the beſt Non-conductor that can be found at hand, as an old chair, a ſtool, &c. "It "is ſtill ſafer (ſays Dr. FRANKLIN) to "bring two or three matraſſes or beds into "the middle of the room, and, folding "them up double, put the chair upon "them; for, they not being ſo good Con- "ductors as the walls, the lightning will "not chooſe an interrupted courſe through "the air of the room and the bedding, "when it can go through a continued "better Conductor, the wall. But where "it can be had, a hammock or ſwinging "bed, ſuſpended by ſilk cords, equally "diſtant from the walls on every ſide, and "from the cieling and floor above and be- "low, affords the ſafeſt ſituation a perſon "can have in any room whatever, and "what indeed may be deemed quite free "from danger of any ſtroke by lightning."

If a ſtorm was to happen whilſt a perſon is in the open fields, and far from any building, the beſt thing he can do is to retire within a ſmall diſtance of the higheſt

tree or trees he can get at; he muſt by no means go quite near them, but ſhould ſtop at about fifteen or twenty feet from their outermoſt branches; for if the lightning ſhould fall thereabout, it will very probably ſtrike the trees; and in caſe a tree was to be ſplit, he is ſafe enough at that diſtance from it.

In regard to the other great uſe of Electricity, *viz.* its application as a medicine, there have been many opinions *pro* and *contra*, and the reputation of medical Electricity has been very dubious and fluctuating; owing to the exaggerations, the miſtakes, the prejudices, and the intereſt of thoſe who have adminiſtered it in phyſical caſes. But after many experiments, and after overcoming the rooted prejudice of ſeveral phyſicians againſt medical Electricity, it has been clearly proved, that, when properly managed, it is an harmleſs remedy, which ſometimes inſtantaneouſly removes divers complaints, generally relieves, and often perfectly cures various diſorders, ſome of which could not be removed by the

utmoſt endeavours of phyſicians and ſurgeons.

It is an important remark, that Electricity, when properly managed, if it does not effect a cure, at leaſt it produces no bad effect. The few caſes in which it ſeems to have produced any harm, are of a doubtful nature.

The remarks made by philoſophers, relating to the effects of Electricity upon the human body in general, are the following; *viz.* that by electrization, whether poſitive or negative, the pulſe of a perſon is quickened, the number of pulſations being generally increaſed about one-ſixth; and that glandular ſecretions, and the inſenſible perſpiration, are promoted, and often even reſtored, when they had been entirely obſtructed. Theſe effects may be proved by ſeveral experiments, independent of phyſical caſes; and I think nobody will deny, that ſuch promotions are not only beneficial, but abſolutely neceſſary for removing ſeveral diſorders. It might be naturally ſuſpected, that the promotion of perſpi-

ration, and of glandular fecretion, were only the confequence of the accelerated pulfation, and not the immediate effect of Electricity: but the contrary is eafily proved, by obferving that, in various cafes, the quickening of the pulfation by other means, independent of Electricity, as fear, exercife, &c. did not promote thofe fecretions nearly fo much, if at all, as electrization; and alfo, that glandular fecretion and perfpiration are often promoted by Electricity, when applied only to a particular part of the body, in which cafe it feldom, if ever, accelerates the pulfation.

Hitherto it has not been difcovered, that the electric fluid acts within the human body by any chymical property, as moft medicines generally do; but its action, by which it produces the above-mentioned effects, may be confidered merely as a mechanical ftimulus; for it feems to act as fuch, even within thofe parts of the body, which, efpecially when difeafed, are moftly out of the reach of other remedies.

Formerly, in order to ftimulate, or in general to apply Electricity to any difeafed part

part of the human body, ſtrong ſhocks, or at leaſt very pungent ſparks, were thought neceſſary; but at preſent it is very reaſonably eſtabliſhed, upon experience, that the greateſt electric powers which can be applied with good expectations, are exceedingly ſmall ſhocks and moderate ſparks, the proper force of which will be particularly deſcribed in the ſequel; but that, in general, the moſt proper treatment is, to throw the fluid by means of a wooden point, as it is commonly called, or merely by a metallic point; in which laſt caſe, the perſon electrified feels only a gentle wind upon that part of the body towards which the point is directed.

By conſidering the above-mentioned effects of Electricity, one may naturally ſuſpect, that in caſes of preternatural diſcharges, the application of Electricity would be rather injurious than beneficial; becauſe in thoſe caſes the diſcharge is required to be ſuppreſſed, and not promoted. In reſpect to this important point, it has been obſerved, that if ſtrong ſhocks, or very pungent ſparks, be given to the patients

afflicted

afflicted with thoſe diſcharges, the diſeaſe is ſeldom cured, and on the contrary is often increaſed; but when only the fluid is drawn from the part, by means of a wooden point, or at moſt exceedingly ſmall ſhocks are adminiſtered, when the ſeat of the diſeaſe is more internal, then the diſcharge, &c. is at firſt generally promoted for a few days or hours, according to the nature of the diſeaſe and other circumſtances, but afterwards it leſſens by degrees, till it is quite cured. In cutaneous eruptions, the application of Electricity is generally attended with ſimilar effects.—The eruption firſt ſpreads farther for a ſhort time, and afterwards leſſens by degrees till it quite vaniſhes. From theſe obſervations it appears, that the application of Electricity, when judiciouſly managed, does not merely promote any diſcharge or circulation of fluids, but rather aſſiſts the *vis vitæ*, or that innate endeavour, by which nature tends to reſtore the ſound ſtate of the injured parts of a living animal. It may perhaps be ever difficult to explain, in what manner Electricity aſſiſts that natural endeavour; but experience ſhews the certainty

tainty of the fact, and with it we muſt be gratefully contented; for we may apply the effects to our wants, though we are ignorant of their cauſe, and of its mode of acting

When an electric ſhock is ſent through any part of the body, an inſtantaneous involuntary motion or convulſion is occaſioned, which ſhews that the muſcular fibres through which the ſhock is ſent, are expanded, or in ſome other manner convulſed. This involuntary motion, though not ſo ſtrongly, is occaſioned alſo by ſparks, and often even by drawing the fluid.—Farther, when a ſhock is ſent through or over ſeveral ſubſtances beſides the human body, a tremulous motion and an expanſion is evidently occaſioned, as may be ſhewn by many electrical experiments. Now all theſe obſervations may perhaps, in a manner, explain the action of Electricity upon the organized parts of an animal body, by comparing it with the tremulous motion given to pipes of any ſort, through which fluids are tranſmitted, in order to accelerate their paſſage, and to prevent any ſtoppage which might

might arife from ftagnation or accumulation of grofs bodies. Perhaps the reafon why ftrong fhocks are generally hurtful, may be becaufe the irritation they give to the obftructed parts, efpecially when they are very minute and delicate, breaks their organization; the force being greater than thofe parts can naturally bear.

Independent of undeniable practical obfervations, when it is only admitted that Electricity promotes natural fecretions and circulation, which it certainly does, there follows, that its application muft be beneficial in cafes of unnatural difcharges; for in thofe cafes the difcharge is occafioned by the obftruction of the natural ways; but Electricity removes thofe obftructions, which is the fame thing as to promote natural fecretion and circulation; therefore, it muft fupprefs the unnatural difcharge, which can no longer exift when the natural courfe of the fluids has been reftored.

With refpect to difeafes in general, two ftates of the affected parts fhould be con-

fidered. The firft is, the immediate and recent caufe of the difeafe; and the fecond ftate is, the alteration of other parts, efpecially folid, which is occafioned by the long continuance of the firft and principal caufe; thus, for inftance, the weaknefs or rupture of fome veffels within the body, may occafion extravafation of fluids, which is the firft ftate of the difeafe. Now if thefe extravafated fluids continue in any part of the body, they will gradually occafion a fuppuration, an inflammation, or other fymptoms, which vary according to innumerable circmftances. This we may confider as the fecond ftate of the difeafe. Again, when a palfy deprives a part of the body of its motion, the flefhy and even the more folid parts, in procefs of time, wafte and become disfigured; which is the effect of the obftructed motion and circulation, and which we may therefore confider as the fecond ftate of the difeafe; and fo of the reft. Now it has been obferved, that the power of Electricity often removes the firft ftate of the diforder; but the latter is very feldom cured by it. Indeed it feems almoft impoffible that a disfigured bone or

deftroyed

deſtroyed organization ſhould be reſtored to its ſound ſtate by means of Electricity. Dr. FRANKLIN having electrified ſeveral paralytic perſons in America, obſerved, that they were generally relieved for a few days at the beginning, but that they afterwards either did not mend, or relapſed into the ſtate they were before the uſe of Electricity *. Here it muſt be obſerved, that thoſe paralyſies were moſtly of a long ſtanding, and alſo that the method practiſed by the Doctor, was to give ſtrong ſhocks, which we have already remarked to be rather prejudicial.

In general, the application of Electricity has been found to be of very little uſe in caſes of long ſtanding; becauſe, as we obſerved above, the more ſolid parts, by the long continuance of the diſorder, have undergone ſuch alteration, as cannot be reſtored by a mere ſtimulus, ſuch as the electric action is ſuppoſed to be. However, ſometimes diſeaſes of many years

* See Dr. FRANKLIN's Philoſophical Letters, Papers, &c. and Dr. PRIESTLEY's Hiſt. of Electricity.

ſtanding

ſtanding have been perfectly cured or relieved by means of Electricity. In theſe caſes, therefore, although there may be leſs hope of effecting a cure, it is not improper to apply the power of Electricity, which, when judiciouſly managed, does never produce any bad effects.

Hitherto, I do not know that any authentic facts have ſhewn any difference between the application of different kinds of Electricity, in medical caſes. Whether the patients be electrified by the prime Conductor, or the inſulated rubber of the uſual electrical machines, *viz.* whether they are electrified poſitively or negatively, ſeems to be quite indifferent.

In reſpect to the caſes in which Electricity may be applied; experience ſhews, that in general, all kinds of obſtructions, whether of motion, or circulation, or of ſecretion, are very often removed or alleviated by Electricity. The ſame may be alſo ſaid of nervous diſorders; both which include a great variety of diſeaſes. To perſons afflicted with the venereal diſeaſe,

or

or to pregnant women, electrization has been thought to be pernicious; but my reader may be aſſured, that even in thoſe caſes it may be uſed without fear, if it be judiciouſly managed. When pregnant women are to be electrified for any diſorder, the ſhocks ſhould be abſolutely forbidden; and even when the other more gentle treatments are uſed, a conſtant attention ſhould be given to any phenomenon that may appear in the courſe of the electrization; the method of which ſhould be increaſed, diminiſhed, or ſuſpended, according as circumſtances may indicate.

Having thus given a ſummary view of the theory of medical Electricity, without entering into the detail of any phyſical caſes, I ſhall reſerve to treat at large of the practical part, for the latter end of this work.

CHAP.

CHAP. X.

Containing a compendious view of the principal properties of Electricity.

AFTER the laws hitherto eſtabliſhed in the ſcience of Electricity have been exhibited at large, and the particulars relating to each have been ſufficiently conſidered, it will not be amiſs to ſhow in how ſmall a compaſs thoſe laws may be reduced, and how narrow is the foundation of all that has hitherto been done.

I doubt not but this recapitulation will prove very ſerviceable to thoſe, who are novices in Electricity, as, by getting in memory a few particulars, they will not only reconcile all that which has been ſaid before, but will alſo be enabled themſelves to explain moſt of the following experiments, and to underſtand the application of the hypotheſis, of which we ſhall next proceed to treat.

All the natural bodies are divided into two claſſes, *i. e.* Electrics and Conductors. Electrics are ſuch as may by ſome means be excited, ſo as to produce Electrical appearances; but Conductors are ſuch as cannot be excited by themſelves, *i. e.* without the interference of an Electric: further, electrical ſubſtances will not tranſmit Electricity, whereas the ſubſtance of Conductors is pervaded by it.

Electricity may be produced four ways, *i. e.* by friction, by heating and cooling, by melting, or pouring one melted ſubſtance into another, and by evaporation.

When two different bodies, except they are both Conductors, are rubbed together, they will both (provided that which is a Conductor be inſulated) appear electrified, and poſſeſſed of different Electricities; ſo when a piece of ſmooth glaſs is rubbed with an inſulated piece of leather, it acquires one kind of Electricity, called the vitreous, poſitive or plus Electricity; and the inſulated leather acquires the other, called

called the resinous, negative or minus Electricity.

The difference between these two Electricities consists principally in the appearances of their light, and in the phenomena of attraction and repulsion.

When the positive Electricity is entering a pointed body, it causes in general the appearance of a lucid star or globule on that point; but the negative Electricity generally shows a lucid pencil of rays seeming to issue from the extremity of the pointed body.

Bodies, possessed of the same Electricity, repel each other; but bodies, possessed of different Electricities, attract each other.

Whenever bodies of any kind come within the sphere of action of an electrified body, except they are very small, and insulated, they become actually possessed of the Electricity contrary to that of the electrified body, to which they are presented.

No Electricity can be obſerved upon the ſurface of any electrified body, except that ſurface is contiguous to an Electric, which Electric can ſomehow or other acquire a contrary Electricity at a little diſtance. Otherwiſe,—no Electricity can appear upon the ſurface of any electrified body, except that ſurface is oppoſite to another body, which has actually acquired the contrary Electricity, and theſe contrarily electrified bodies are ſeparated by an Electric *.

If

* On conſidering this principle, it may be aſked, why any Electricity can be obſerved upon the ſurface of an electrified body, that is inſulated at a conſiderable diſtance from other Conductors? Or, which is the Electric, that is contiguous to the ſurface of an electrified Conductor, or excited Electric, and which has actually acquired a contrary Electricity at a little diſtance from the ſaid ſurface? To this queſtion is anſwered, that the air is in general the Electric, which is oppoſite to the ſurface of any electrified body, which being not a perfect electric, does eaſily acquire a contrary Electricity on a ſtratum of its ſubſtance, that is at a little diſtance from the electrified body; and in conſequence of this ſtratum, it acquires another ſtratum contrarily electrified, and at a little diſtance from the former; to this, other ſtrata ſucceed, alternately poſſeſſed of poſitive and negative Electricities,

If the repulsion existing between bodies possessed of the same kind of Electricity be excepted, all the other electrical phenomena are occasioned by the passage of Electricity from one body to another.

A considerable quantity of Electricity exists in the atmosphere, and is certainly employed for some great purposes of nature.

The air, the clouds, the rain, the hail, the snow, and the fogs, are almost always electrified; but electrization has not been found to promote or retard coagulations, or the freezing of water.

These few laws, well considered, will be found to contain almost all that is known of the subject, and if properly applied, they

cities, and decreasing in power until they vanish, or come to the walls of the room, &c. The experiment of the glass tube, mentioned in the VIth chapter, shows that, in general, when an Electric, sufficiently dense, is presented to an electrified body, it acquires successive zones, or strata of positive and negative Electricity.

may explain moſt of the experiments that follow.

Beſides what has been ſaid in this part of the preſent Treatiſe, there are ſeveral other maxims, rules, &c. to be known in Electricity; but as theſe moſtly reſpect the real practice, ſo they will be occaſionally inſerted in other places, that ſeem better adapted to their reception.

PART

PART II.

THEORY OF ELECTRICITY.

CHAP. I.

The Hypothesis of Positive and Negative Electricity.

IT is the business of Philosophy to collect the history of appearances, and from these to deduce such mechanical laws, as may either be themselves of immediate use, or lead to the discovery of other facts more interesting and necessary for the happiness of human kind. After a number of such constant appearances, which are called natural laws, have been established, and confirmed by a sufficient number of experiments, it is then proper to investigate the cause of those effects; which, if it be once discovered, and its mode of acting be ascertained, puts an end to the trouble of experimental investigation, and renders the application of its effects certain, and determinate.

Caufes and effects are fo intimately connected and dependent on each other, that throughout the fyftem of nature we every where difcover a feries of energies, which whilft they are depending on, and derived from, their preceding terms, are at the fame time the caufes of their fucceeding ones. But what is the firft caufe of all the reft, which being not the effect of any preceding, may be called the fource of all, and the firft term in the feries? In contemplating this fource, the mind is loft in wonder, and, after we are advanced a few fteps, we find that a cloud obftructs our further progrefs, and, from continuing our inquiry and contemplation, nothing more can be derived but an argument to prove the imbecility and fhortnefs of our underftanding. This however is not the fubject of the prefent Treatife; and all I meant to deduce is, that, after the laws of Electricity have been confidered, it is neceffary that we fhould go a little further, and inveftigate, if poffible, the immediate caufe of that property in nature, or confider the moft probable conjectures that have been offered on this fubject: by the knowledge of which we may explain all

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the known electrical appearances, and adapt their effects to our purposes with somewhat more certainty and precision.

The vast number of hypotheses that have been framed in explaining the electrical phenomena, from the infancy of the science to the present time, may be easily imagined, by considering the great number of labourers, and the discoveries that have been produced without intermission in this field of wonders. It would be not only an endless work to relate all the hypotheses hitherto offered, but also an useless one, when they have been evidently contradicted by several experiments, and after they have all given place to the hypothesis of a single electric fluid, which generally goes under the name of Dr. FRANKLIN's. That although this hypothesis explains all the known electrical appearances, it is however not a demonstrable truth, but the most probable supposition, I confess; and, in order that a due distinction might be preserved between the knowledge of facts, and the supposition of their immediate cause, I have separated the former from the latter, and followed that method

method which ſeemed more philoſophical and inſtructive; but now to make further apologies for admitting this hypotheſis, at a time when numberleſs experiments ſpeak clear in its favour, would be doing an injury to the philoſophical world in general, and eſpecially to the ingenious philoſophers that propoſed and improved it. I ſhall therefore, without further preamble, lay it down as it is now commonly and reaſonably admitted; and ſhall uſe it in the explanation of the following experiments.

All the phenomena called Electrical are ſuppoſed to be effected by an inviſible ſubtile fluid exiſting in all the bodies of the earth. It is ſuppoſed alſo that this fluid is very elaſtic, *i. e.* repulſive of its own particles, but attractive of the particles of other matter.

When a body does not ſhow any electrical appearances, it is then ſuppoſed to contain its natural quantity of electric fluid (but whether that quantity bears any proportion to the quantity of matter in general, or not, is uncertain), and therefore that body is ſaid

ſaid to be in its *natural* or *non-electrified ſtate*: but if a body ſhows any electrical appearances, it is then ſaid to be electrified, and it is ſuppoſed that it has either acquired an additional quantity of electric fluid, or that it has loſt ſome of its natural ſhare. A body having received an additional quantity of electric fluid, is ſaid to be *overcharged*, or *poſitively electrified*; and a body that has loſt part of its natural quantity of electric fluid, is ſaid to be *undercharged*, or *negatively electrified*.

From hence it appears, why the terms *poſitive* and *negative*, or *plus* and *minus* Electricity came to be uſed; for the firſt ſignifies a real plus, or ſuperfluity, and the ſecond a real minus, or deficiency of the quantity of electric fluid proper to a body.

By this hypotheſis, which is analogous to the other phenomena of nature, the electrical appearances are eaſily explained, and there is not a ſingle experiment that ſeems to contradict it. Firſt it appears, that when an electric and a conducting ſubſtance are rubbed together, the Electricity is not then produced; but by the action of rubbing, one

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body pumps, as it were, the electric fluid from the other*: hence, if one becomes overcharged with it, or positively electrified,

* By what mechanism one body extracts the electric fluid from the other is not yet known. The celebrated Father BECCARIA supposes that the action of rubbing increaseth the capacity of the Electric, *i. e.* renders that part of the Electric, which is actually under the rubber, capable of containing a greater quantity of electric fluid; hence it receives from the rubber an additional share of fluid: which is manifested upon the surface of the Electric, when that surface is come out of the rubber; in which state it loses, or, as it were, contracts its capacity. Father BECCARIA's experiment to prove this supposition is the following:—He caused a glass plate to be rubbed by a rubber applied on one side of the plate, while it was turning vertically; and holding at the same time a linen thread on the other side of the plate, just opposite to the rubber, he observed, that the thread was not attracted by that part of the glass which corresponded to the rubber, but by that which was opposite to the surface of the glass that had just come out of the rubber; which shews that the fluid acquired by the glass plate, did not manifest its power until the surface of the glass was come out of the rubber. But, query, in what manner does the glass augment its capacity of holding the electric fluid by the action of the rubber? See Dr. FRANKLIN's Letters, &c. § 34. Besides this, there are other experiments to be mentioned in the course of this work, which clearly shew that the capacity of a body to hold Electricity is increased by the vicinity of certain other bodies.

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the other muſt neceſſarily be undercharged, or electrified negatively, except its deficiency be ſupplied by other bodies communicating with it. From hence alſo appears the reaſon, why, when an Electric is rubbed with an inſulated rubber, it can acquire but little Electricity; becauſe in that caſe, the rubber, not communicating with other Conductors, can ſupply the Electric with only that ſmall quantity of fluid which belongs to itſelf, or which it collects from the contiguous air.

Electric attraction is eaſily explained; for this does not exiſt, except between bodies differently electrified; which muſt certainly attract each other, on account of the attraction exiſting between the ſuperfluous electric fluid of the bodies electrified poſitively, and the undercharged matter of the bodies electrified negatively.

As to the repulſion exiſting between bodies poſſeſſed of the ſame Electricity; in order to underſtand its explanation thoroughly, the reader muſt be reminded of the principle mentioned in the preceding part, which is, that no Electricity, *i. e.* the electric

tric fluid proper to a body, can neither be augmented nor diminiſhed upon the ſurface of that body, except the ſaid ſurface is contiguous to an Electric, which can acquire a contrary Electricity at a little diſtance; from whence it follows, that no Electricity can be diſplayed upon the facing ſurfaces of two bodies that are ſufficiently near one another, and both poſſeſſed of the ſame Electricity; for the air that ſtands between thoſe contiguous ſurfaces has no liberty of acquiring any contrary Electricity. This being premiſed, the explanation of Electric repulſion becomes very eaſy. Suppoſe, for inſtance, that two ſmall bodies are freely ſuſpended by inſulated threads, ſo that when they are not electrified they may hang contiguous to one another. Now ſuppoſe thoſe bodies to be electrified either poſitively or negatively, and then they muſt repel one another; for either the increaſed, or the diminiſhed natural quantity of electric fluid in thoſe bodies, will endeavour to diffuſe itſelf equally over every part of the ſurfaces of thoſe bodies; and this endeavour will cauſe the ſaid bodies to recede from each other, ſo that a quantity of air may be interpoſed between their ſurfaces, ſufficient

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to acquire a contrary Electricity at a little distance from the said surfaces.—Otherwise, if the bodies, possessed of the same Electricity, do not repel each other, so that a sufficient quantity of air may be interposed between their surfaces, the increased quantity of electric fluid, when the bodies are electrified positively, or the remnant of it, when the bodies are electrified negatively, by the above principle, cannot be diffused equally throughout, or over the surfaces of those bodies; for no Electricity can appear upon the surfaces of bodies in contact, or that are very near one another. But the electric fluid, by attracting the particles of matter, endeavours to diffuse itself equally throughout, or over the surfaces of those bodies; therefore the said bodies are, by this endeavour, forced to repel one another.

I think it is unnecessary to insist further upon the above explanation; for the principle, upon which it depends, seems universal and clear, so that it may be easily applied to explain electric repulsion in general, as well as the repulsion between the above-mentioned two bodies.

The

The charging of coated glaſs, and other Electrics, as well as the other phenomena of Electricity, may alſo be eaſily accounted for by the above-mentioned hypotheſis of Electricity; but I think it unneceſſary to enumerate and account for all the particulars in this place, as we ſhall have occaſion to ſpeak of them in the explanation of the experiments in the third part.

C H A P. II.

Of the Nature of the electric Fluid.

THE human mind, never ſatisfied, after the cauſe of ſome effects has been diſcovered, or only gueſſed at, attempts to inveſtigate ſome more intimate quality, and even the origin of that ſuppoſed cauſe, making further ſuppoſitions, and framing other hypotheſes, which, by the courſe of things, muſt certainly be leſs probable than the former. This unlimited endeavour to acquire knowledge is often too ridiculous to be purſued, on account of its abſtruſeneſs and uncertainty, eſpecially when the ſteps immediately preceding the ſubject in hand have but a ſmall degree of probability. It is from hence that Philoſophers have frequently

quently ſpent a great deal of time, and trouble, in attempting to diſcover the properties and cauſes of what exiſted only in their own imaginations. Sometimes, however, when a ſuppoſed exiſtence comes ſo very near to truth, that the moſt ſceptic Philoſopher heſitates not to confeſs the probability of it, or when he can invent no argument to evince the contrary, then it is not only allowable, but neceſſary for the buſineſs of Philoſophy, to purſue the inquiry further, and, if nothing elſe can be aſcertained, at leaſt to propoſe ſome further conjectures upon the former hypotheſis. This now is the caſe in the ſcience of Electricity; and after we have related the moſt plauſible hypotheſis as yet offered, *i. e.* that of a ſingle elaſtic fluid, we come in this place to conſider the eſſence of this fluid, in order if poſſible, that we might attain to, at leaſt, ſome probable conjecture reſpecting its materials.

When nothing more than electric attraction and repulſion had been obſerved, Electricians ſuppoſed that theſe were effected by a kind of unctuous effluvia proceeding immediately from the electrified body; but

when the light, the burning quality, the phoſphoreal ſmell, &c. was perceived to be produced by excited Electrics, then it was naturally ſuppoſed, that the electric fluid was of the ſame nature with fire. This opinion has prevailed much among ſeveral Philoſophers, and it is from hence, that the electric fluid has been commonly called Electric Fire. Beſides this ſuppoſed identity of the electric fluid, and the element of fire, there have been two other opinions concerning the eſſence of this fluid; it having been thought by ſome to be the *ether* of Sir ISAAC NEWTON, and by others (whoſe opinion ſeems to be the moſt probable) to be a fluid *ſui generis*, *i. e.* different from all other known fluids.

In order the more regularly to examine theſe conjectures, it will be neceſſary to premiſe ſomething in regard to the nature of fire, at leaſt ſo much as is ſufficient for the preſent purpoſe.

The element of fire may be conſidered in regard to its origin, to the different ſtates of its exiſtence, and to its effects. In regard to its

its origin it is commonly ſpecified under the names of Celeſtial, Subterraneous, and Culinary Fire; underſtanding by the firſt, that which proceeds from the ſun, and, by being diſperſed throughout the univerſe, gives life and motion to almoſt every thing that exiſts; by the ſecond, that which is the cauſe of volcanos, hot ſprings, &c. and laſtly, under the name of Culinary Fire, underſtanding that which is commonly produced upon the earth, by burning ſeveral ſubſtances. Theſe diſtinctions however are little if at all uſeful; for, whatever be the origin of fire, its effects are always the ſame.

In reſpect to the different ſtates of its exiſtence, the Chymiſts know only two; the firſt obvious one, and indeed that, to which only is given the name of Fire, is that actual agitation of the particles of that element, which produces the complex idea of lucid, hot, &c. that is commonly underſtood under the name *Fire*; and the other ſtate is the real principle of fire exiſting as a conſtituent principle in ſeveral, and perhaps all ſubſtances; or, that matter, whoſe particles, when agitated in a peculiar and

violent manner, produce the common ſen-ſible fire.

This, which we may call fire in an inactive ſtate, is the *Phlogiſton* of the Chymiſts, and is that, which when united in a ſufficient quantity with other ſubſtances, renders them inflammable. It ſeems evident that this principle does really exiſt; for we may transfer it from one body to another; we may render a body inflammable, which in its own nature is not ſo, by ſuperinducing on it the phlogiſton; and we may reduce a body naturally inflammable, to a ſubſtance not inflammable, by depriving it of its phlogiſton.

Now the electric fluid, as far as we can determine, bears but a very ſmall reſemblance to the above-mentioned two ſtates of fire; for although it exiſts in different bodies, as the phlogiſton, yet when we compare its other attributes with thoſe of fire, we then immediately perceive it to be not the ſame, but a different principle. In the firſt place, if they were both the ſame thing, they ſhould be always together, and where-

ever

ever a certain quantity of fire exiſts, there the ſame quantity of electric fluid ſhould be found; but this is contrary to experiments; for a piece of metal or other ſubſtance may acquire a great degree of heat without appearing at all electrified; and on the other hand, may be ſtrongly electrified without acquiring by it any ſenſible degree of heat, or any addition to its phlogiſton. Secondly, fire penetrates every known ſubſtance, and an exceedingly ſmall quantity of it is diffuſed alike throughout bodies of every kind; whereas the electric fluid pervades only Conductors *. Thirdly, the electric fluid goes through a very long Conductor in a ſpace of time almoſt inſtantaneous; but fire is very ſlowly propagated. I might enumerate ſeveral other improprieties attending this hypotheſis of the ſameneſs of fire and the electric fluid, but thoſe already mentioned are, I think, ſufficient to induce my readers to ſuppoſe otherwiſe.

* Here may be obſerved, that heat pervades more eaſily the ſubſtance of ſome good Conductors of Electricity; the rule however is not general.

Dr. PRIESTLEY, on obſerving that the electric exploſion, taken in different kinds of air, acts, in general, like other phlogiſtic proceſſes, ſuppoſes that the electric matter either is, or contains, phlogiſton *. In regard to this, I would obſerve, that there is no neceſſity of ſuppoſing the electric matter either to be, or contain phlogiſton, on that account; for the phlogiſton, in this caſe, may, by the force of the electric exploſion, be extricated, either from the ſurface of the Conductors, between which the exploſion is taken, or from particles of heterogeneous matter floating in that air, in which the exploſion is made †.

In regard to the ſimilarity between the effects of fire, and the effects of the electric fluid, it will be very obvious to remark, that although fire is in ſeveral inſtances produced by the electric fluid, yet we ſhould never confound the one with the other, and

* Obſervations on different Kinds of air, vol. II. ſec. XIII.

† See my Treatiſe on Air, &c. p. 433.

conſider

confider them both as the fame thing; for it is well known that friction produces fire, and it is by no means furprifing that the electric fluid, by the rapidity of its motion, through fubftances, that in fome manner obftruct its paffage, fhould generate light, heat, rarefaction, and the other effects of fire *.

Mr. HENLY, in confequence of feveral very interefting experiments, made by himfelf, fuppofed, that, although the electric fluid may be neither phlogifton nor fire, yet that it is a modification of that element, which, while in a quiefcent ftate, is called Phlogifton, and when violently agitated is called Fire. We conftantly obferve (fays he) I. That if two bodies that have an equal quantity of phlogifton (which is the cafe with bodies of the fame kind, as glafs and glafs, metal and metal, &c.) be rubbed together, they acquire either very little, or no Electricity at all. II. That as one of

* Here it is proper to obferve, that the electric fluid fhows no effects of fire, except when it goes through fome medium that obftructs its free paffage.

the bodies has a greater quantity of phlogiſton than the other, ſo they acquire a greater quantity of Electricity, as when glaſs is rubbed with metal. III. That a certain degree of friction produces Electricity, and that a more violent friction produces fire, but no Electricity, as may be obſerved by rubbing together two pieces of baked wood, of glaſs, &c. IV. And that in general, bodies, poſſeſſed of a greater quantity of phlogiſton, give the electric fluid to bodies that have leſs of it, *i. e.* they acquire the negative Electricity, when rubbed with bodies that have a leſs quantity of phlogiſton *.

* Mr. HENLY, in order to try what Electricity different ſubſtances would acquire, inſulated them upon ſticks of ſealing wax, and rubbed them againſt his woollen coat, or waiſtcoat. In this manner he tried a vaſt number of vegetable, animal, mineral, and artificial ſubſtances; and he diſcovered a very remarkable law, which is, that ſuch ſubſtances, which have a great quantity of phlogiſton, as vegetable ſubſtances, and particularly the hot, aromatic plants and ſeeds, &c. *give* the electric fluid; that is, they acquire the negative Electricity when rubbed againſt the woollen cloths; and, that ſuch ſubſtances, which have but little plogiſton (as moſt animal ſubſtances) *acquire* the electric fluid from the ſaid cloths, *i. e.* they are electrified poſitively. See the Phil. Tranſ. for the year 1777.

From

From theſe obſervations we gather, that the electric fluid, and fire, are produced by ſimilar operations, and are both extracted from bodies abounding with phlogiſton: and hence he concludes, that the phlogiſton, the electric fluid, and fire, are only different modifications of the very ſame element; the firſt being its quieſcent ſtate of exiſtence, the ſecond its firſt active, and the laſt its more violent ſtate of agitation: like fermentation producing firſt wine, ſecondly vinegar, laſtly putrefaction.

As to the identity of the Electric, and the ethereal fluid, it ſeems to me quite an improbable, or rather a futile and inſignificant hypotheſis; for this ether is not a real, exiſting, but merely an *hypothetical*, *fluid*, ſuppoſed by different Philoſophers to be endued with different properties, and to be an element of ſeveral principles. Some ſuppoſe it to be the element of fire itſelf, others make it the cauſe of attraction, others again derive animal ſpirits from it, &c.; but the truth is, that not only the eſſence, or properties, of this fluid, but even the reality of its exiſtence is abſolutely unknown.

According

According to Sir ISAAC NEWTON's ſuppoſition, this ether is an exceedingly ſubtle and elaſtic fluid, diſperſed throughout all the univerſe, and whoſe particles repel the particles of other matter. But on this ſuppoſition the electric fluid is different from ether; for, although the former is ſubtle, and elaſtic, like the latter, yet (as Dr. PRIESTLEY obſerves) it is not repulſive like the ether, but attractive of all other matter.

CHAP. III.

Of the Nature of Electrics and Conductors.

THE remarkable difference exiſting between the two claſſes of bodies in regard to Electricity, *i. e.* Electrics and Conductors, naturally induces an Electrician to inquire what is that principle in bodies, or by what mechaniſm ſome ſubſtances become capable of tranſmitting the electric fluid, whilſt others are impervious to it?

In regard to the explanation of theſe two remarkable properties, there have been, as might be expected, ſeveral conjectures offered; but, except one probable hypotheſis, there is nothing as yet aſcertained. When the catalogue of Electrics and Conductors was very ſhort and imperfect, it was ſuppoſed that the only two conducting principles were metals, and water; and that all ſubſtances were nearer, or further from the nature of a perfect Conductor, in proportion as they contained a greater or leſs quantity

tity of the above principles in their composition. Wood, for inſtance, was ſuppoſed to be a Conductor only on account of the water it contained within its pores; accordingly, it was obſerved, that the greater quantity of moiſture the wood contained, the better Conductor it proved to be, and on the contrary, that it acted more like an Electric, in proportion as it was freed from its moiſture. But when water itſelf was obſerved to be a bad Conductor, and hot air, and charcoal to be good Conductors, eſpecially the latter, which ſubſtances, it is well known, contain no water nor metal, at leaſt not in ſuch a quantity as is ſufficient to change a non-conducting ſubſtance into a Conductor, then the former ſuppoſition was laid aſide, and another was offered by Dr. PRIESTLEY, in his ſecond volume of Obſervations on the different Kinds of Air *, which ſeems to be well founded.

The Doctor, conſidering what the principle is, which Conductors poſſeſs in com-

* Sec. XIV.

mon,

mon, and finding one of their common ingredients to be the phlogiſton, deduces from thence, that the conducting quality is abſolutely owing to the phlogiſton. "Had there been (ſays he) any phlogiſton "in water, I ſhould have concluded, that "there had been no conducting power in "nature; but in conſequence of ſome "union of this principle with ſome baſe. "In this, metals and charcoal exactly "agree:—while they have the phlogiſton, "they conduct; when deprived of it, they "will not conduct."

And in a note to this paragraph, he ſubjoins:

"Having ſince found, that long agitation "in the pureſt water injures air, ſo that "a candle will not burn in it afterwards, "which is preciſely the effect of all phlogiſtic proceſſes, I now conclude that the "maxim, ſuggeſted in this paragraph, is "univerſally true."

This hypotheſis ſeems very ingenious and probable; and, till any other more

plauſible

plausible be offered, or experiments contradict it, I think we may safely make use of it in pursuing our electrical investigations, and endeavour to reconcile to it the phenomena already discovered in Electricity.

CHAP. IV.

Of the Place occupied by the electric Fluid.

BEFORE we quit the hypothetical part of this Treatise, it may be proper to say something concerning the residence of the electric fluid, either natural to a body, or superinduced on it. That the electric fluid, proper to a body when in its natural state, is equally diffused throughout all its substance, I think no one will deny; because that fluid is attractive of the particles of all other matter, and the particles of other matter are attractive of the electric fluid; and as this attraction is in proportion to the quantity of homogeneous matter, any quantity of matter will certainly attract a quantity of electric fluid proportionable to itself; therefore, the electric

electric fluid muſt be equally diffuſed throughout all the parts of that portion of matter. This propoſition, however, will take place only in ſpeaking of Conductors; for it is founded upon the ſuppoſition, that the electric fluid, proper to a body in its natural ſtate, does freely pervade that ſubſtance; but whether this is a fact reſpecting Electrics, or not, hath not hitherto been aſcertained. As far as may be judged from experiments, I ſhould ſuppoſe this rule to hold good with Electrics alſo; and my ſuppoſition is founded upon the following reaſoning:—All the Electrics, when made very hot, become Conductors *; in that ſtate, therefore, the above rule muſt hold good, *i. e.* the electric fluid, proper to their quantity of matter, muſt be equally diffuſed throughout their ſubſtance: and as all the Electrics in nature, before they became ſuch (we may ſuppoſe) were Conductors; in that ſtate they certainly had

* As this propoſition has been found true in all the experiments hitherto made, I think it may be conſidered very properly, as a general law in the ſcience of Electricity.

their

their proper ſhare of fluid. Now as they afterwards cool, and become Electrics, it ſhould ſeem that the change of their nature could not affect the equal diffuſion of the electric fluid, which took place whilſt they were in a conducting ſtate *. In conſequence of this conſideration, the difference between a Conductor and a Non-conductor, in regard to their natural quantity of electric fluid, is that in the former, the fluid may eaſily move, whereas in the latter, it is confined in its pores. But it may be aſked, whether a quantity of electric matter contains as much electric fluid as an equal quantity of conducting matter; a piece of roſin, for inſtance, when melted, does it contain more, leſs, or the ſame quantity, of electric fluid as when cold? To this queſtion I can give no ſatisfactory anſwer; for, by the experiments hitherto made, nothing certain has been deter-

* The only conſideration which ſeems to oppoſe ſome difficulty to this hypotheſis, is the property which ſeveral electric ſubſtances have of becoming electrical by cooling or coagulating. See the 4th chap. of the preceding part.

mined. Dr. PRIESTLEY, in order to afcertain this matter, made the following experiment:—He made a piece of glafs red-hot (in which ftate it is a Conductor) and placing it upon an infulated piece of copper, left it in that fituation till quite cold (*i. e.* till it became an Electric); but in all the time of its cooling, no Electricity of any kind was perceived, either in the copper or glafs; which would have certainly been the cafe, if the piece of glafs had contained either more or lefs fluid when in an Electric, than when in a conducting ftate *. This experiment feems to give a decifive anfwer to the above queftion; but when the experiments, mentioned in the firft part, of melting an electric fubftance into another, and other facts of a fimilar nature, are duly confidered, they feem to make the anfwer again difficult †. It muft therefore be confeffed,

* Hiftory of Electricity, p. 716.—Experiments of a fimilar nature are met with in BECCARIA's Electricifmo Artificiale.

† The wax-chandlers, in forming their mafs into fticks, &c. find it fo ftrongly attractive of duft, &c.

feſſed, that this matter remains as yet unſettled; and nothing but further experiments, and the diſcovery of other facts, can determine any thing ſatisfactory about it.

In reſpect to the place occupied by the electric fluid ſuperinduced on a body, it has been thought, by ſeveral ingenious perſons, that, when a body is electrified, all the ſuperfluous fluid, or all the deficiency of it, in caſe the body is electrified negatively, reſides as a kind of atmoſphere all around the body; to this atmoſphere they attribute the phoſphoreal ſmell, and that tickling ſenſation produced by an excited Electric; and they even ſuppoſe that theſe atmoſpheres may be made viſible. But to this aſſertion it is anſwered by others, that if the Electricity communicated to a body did reſide round it like an atmoſphere, it ſhould certainly repel the air contiguous to that body; but this is not the reſult of experiments;

that they are obliged to uſe great caution in keeping it at a ſufficient diſtance from the charcoal fire, over which they work, leſt it ſhould (as ſometimes happens) cover itſelf with aſhes, and thus ſpoil the work.

periments; for it has been found that the electric atmoſphere, however denſe, if it does at all exiſt, has no effect upon the air contiguous to the electrified body, nor has the motion of the air, even a violent wind, any effect upon the atmoſphere. In regard to the above-mentioned ſenſations of phoſphoreal ſmell, &c. it is thought that they are only occaſioned by the electric fluid entering or going out of the ſkin in a very ſubdivided manner.

From what may be deduced from experiments, it appears that, although the electric fluid is tranſmitted through the ſubſtance of Conductors, yet no communicated Electricity can be obſerved within a ſufficiently narrow cavity of an electrified body; beſides, if two bodies of the ſame ſize and figure, but of different denſities, are electrified together, and afterwards ſeparated, they will acquire each the ſame quantity of Electricity; *i. e.* the Electricity that they acquire will be proportional to their ſurfaces, and not to their reſpective quantities of matter.

We may laſtly conclude, that the Electricity communicated to a body, lies not diffuſed throughout the ſubſtance of that body, but on that ſurface of it which is contiguous to a free Electric, *i. e.* to an Electric, that is not ſurrounded by an homologous Electricity.

PART III.

PRACTICAL ELECTRICITY.

CHAP. I.

Of the electrical Apparatus in general.

HITHERTO we have treated of Electricity only theoretically, having noted what has been found uniformly certain relative to this ſubject, and having exhibited a view of the moſt probable conjectures offered in explanation of electrical appearances; but Electricity being a ſcience that requires a more practical management, than perhaps any other branch of natural philoſophy, it is neceſſary that we ſhould now treat of it practically, and give the beſt directions we are able, both in regard to the conſtruction of the neceſſary apparatus, and to the performance of the experiments not only requiſite in proving

the foregoing Propositions, but such also as are pleasing and entertaining.

In this part of my work the reader will perhaps find more novelty than he expects; for, considering the number of books that have been lately published on this subject, one would imagine that all the experiments possible to be exhibited with an electrical machine, and its appendages, have already been described. The case however is much the contrary; for not only the old experiments have been diversified, but a variety of new ones have been invented, and even the principal part of the apparatus has undergone several changes and improvements.

In order the more regularly to proceed in the description of the electrical apparatus, it will not be improper to divide its parts into three classes; considering in the first, the instruments necessary to produce Electricity; in the second, those proper to accumulate, retain, and employ it; and lastly, those necessary to measure its quantity, and ascertain its quality.

The

The principal inſtrument to produce Electricity, is the electrical Machine, *i. e.* a machine capable by any means of exciting an Electric, ſo as to produce electrical appearances. The conſtruction of thoſe machines, from their firſt invention to the preſent time, has undergone ſo many changes, and their forms have been ſo much varied, that it would be very difficult, and even tedious, to deſcribe thoſe only which are moſt frequently in uſe. Every maker, and almoſt every Electrician, conſtructs his own machines in a manner different from the reſt; and, as new facts or long practice points out ſome imperfections, the Electrician is ready to contrive a new method to correct the preceding errors. Indeed the rapid advance of the ſcience is moſtly owing to this change, and variety of conſtructions; for whether caſual, or deſigned, a new conſtruction has generally either produced ſome diſcovery of importance, or expoſed ſome defect in the apparatus, and management of the ſame.

That the reader may be left at the

liberty of choosing the form of his machine, I shall in this chapter lay down the most necessary rules to construct electrical machines in general; and shall reserve for the next chapter the particular description of some machines, that are the most useful, and which contain all the improvements hitherto made.

The principal parts of the machine are the Electric, the moving Engine, the Rubber, and the prime Conductor, *i. e.* an insulated Conductor, which immediately receives the Electricity from the excited Electric.

The Electric was formerly used of different substances, as glass, rosin, sulphur, sealing-wax, &c.; and of different forms, as cylinders, globes, spheroids, &c. This diversity then obtained on two accounts; first, because it was not ascertained, which substance or form would answer best; and secondly, on account of producing a negative or positive Electricity, at the pleasure of the operator; for before the Electricity

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of the inſulated rubber was diſcovered, ſulphur, rough glaſs, or ſealing wax, was generally uſed for the negative Electricity. At preſent, ſmooth glaſs only is uſed; for when the machine has an inſulated rubber, the operator may produce poſitive or negative Electricity at his pleaſure, without changing the Electric. In regard to the form of the glaſs, thoſe commonly uſed at preſent are globes and cylinders. The moſt convenient ſize for a globe, is from nine to twelve inches diameter: they are made with one neck, which is cemented * to a ſtrong braſs cap, in order to adapt them to a proper frame. The cylinders are made with two necks; they are moſtly uſed without any axis †, and their more uſual ſize is from four inches diameter and eight inches long,

* The beſt cement for electrical purpoſes is made with two parts of roſin, two of bees-wax, and one of the powder of red okre. Theſe ingredients are melted, and mixed together in any veſſel over the fire; and afterwards kept for uſe. This kind of cement ſticks very faſt, and is much preferable to roſin alone, as it is not ſo brittle, and at the ſame time inſulates equally well.

† It is not improper to ſtrengthen the very large cylinders by means of a glaſs axis, viz. a ſolid ſtick of glaſs from one cap to the other.

to twelve or eighteen inches diameter and two feet long; though ſome have been made in London even of twenty-four inches in diameter. The glaſs generally uſed is the beſt flint, though it is not yet abſolutely determined, which kind of metal is the beſt for electrical globes, or cylinders. The thickneſs of the glaſs ſeems immaterial, but perhaps the thinneſt is preferable. It has often happened, that glaſs globes, and cylinders, in the act of whirling, have burſt in innumerable pieces, with great violence, and with ſome danger to the by-ſtanders. Thoſe accidents are ſuppoſed to happen when the globes, or cylinders, after being blown, are ſuddenly cooled. It will therefore be neceſſary to enjoin the workman to let them paſs gradually, from the heat of the glaſs-houſe, to the atmoſpherical temperature.

It has been long queſtioned whether a coating of ſome electric ſubſtance, as roſin, turpentine, &c. on the inſide ſurface of the glaſs, has any effect to increaſe its electrical power; but now it ſeems pretty well determined, that if it does not increaſe the power of a good glaſs globe or cylinder, at

leaſt it does conſiderably improve a bad one. I have ſeveral times put a coating of roſin on the inſide ſurface of phials and tubes, and have conſtantly found that the worſt of them received ſome improvement by it.

The moſt approved compoſition for lining glaſs globes, or cylinders, is made with four parts of Venice turpentine, one part of roſin, and one part of bees-wax. This compoſition muſt be boiled for about two hours over a gentle fire, and muſt be kept ſtirring very often: afterwards it is left to cool, and reſerved for uſe. When a globe or cylinder is to be lined with this mixture, a ſufficient quantity of it is to be broken into ſmall pieces, and introduced into the glaſs; then, by holding the glaſs near the fire, the mixture is melted, and equally ſpread over all its internal ſurface, to about the thickneſs of a ſixpence. In this operation care muſt be taken, that the glaſs be made hot gradually, and be continually turned, ſo as to be heated equally in all its parts, otherwiſe it is apt to break in the operation.

In

In respect to the Engine which is to give motion to the Electric, multiplying wheels have been generally used; which, properly adapted, might give the Electric a quick motion, while they are conveniently turned by a winch. The usual method is, to fix a wheel on one side of the frame of the machine, which is turned by a winch, and has a groove round its circumference. Upon the brass cap of the neck of the glass globe, or one of the necks of the cylinder, a pulley is fixed, the diameter of which is about the third or fourth part of the diameter of the wheel; then a string or strap is put over the wheel and the pulley, and by these means, when the winch is turned, the globe or cylinder makes three or four revolutions, for one revolution of the wheel. There is an inconvenience generally attending this construction, which is, that the string is sometimes so very slack, that the machine cannot work. To remedy this inconvenience, the wheel should be made moveable with respect to the Electric, so that by means of a screw it might be fixed at the proper distance; or else the

pulley

pulley ſhould have ſeveral grooves of different radii on its circumference.

It has been cuſtomary with ſome, to turn the cylinder ſimply with a winch, without any accelerated motion; but that has not been thought ſufficient to produce the greateſt electric power, the glaſs is capable of giving; for the globe or cylinder ſhould properly make about ſix revolutions in a ſecond, which is more than can be conveniently done with the winch only. This method, however, has been lately adopted by Mr. NAIRNE, who, by a nice conſtruction of every part, has produced a very powerful electrical machine; of which I ſhall give a deſcription in the ſequel.

Inſtead of the pulley and the ſtring, as above deſcribed, a wheel and pinion, or a wheel, and an endleſs ſcrew, has been alſo uſed. This conſtruction anſwers perhaps as well as any other; but it muſt be conſtructed with great nicety, otherwiſe, it is apt to make a diſagreeable rattling, and without frequent oiling, ſoon wears away by the great friction of its parts.

The

The next thing belonging to the Electrical machine, neceſſary to be deſcribed, is the rubber, which is to excite the Electric. The rubber, as it is now made, is nothing more than a ſilk cuſhion ſtuffed with hair; and over this cuſhion is put a piece of leather, on which ſome amalgam * has been rubbed, ſo as to ſtick as faſt as poſſible to the leather. Some time ago it was generally uſed, and it is now cuſtomary alſo, to make the rubber of red baſil ſkin ſtuffed with hair; but the ſilk one, as above deſcribed (which is an improvement of Dr. NOOTH) is much preferable. If this ſilk cuſhion, on account of adapting it to the ſurface of the glaſs, is to be fixed upon a metal plate, then care ſhould be taken to make the plate free from ſharp points, edges, or corners,

* The amalgam has been found to excite ſmooth glaſs moſt powerfully. Any metal, diſſolved in quickſilver, will perhaps do equally well, but the amalgam that has been generally uſed, is made with two parts of quickſilver and one of tin-foil, with a ſmall quantity of powdered chalk, mixed together until it becomes a maſs, like paſte. An amalgam made with one part of zinc, and four or five parts of mercury, anſwers ſtill better, as diſcovered by Dr. HIGGINS. *Moſaic gold* may alſo be uſed.

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and it ſhould be as much as poſſible concealed, or covered with ſilk. In ſhort, to conſtruct the rubber properly, it muſt be made in ſuch a manner, that the ſide of it, which the ſurface of the glaſs enters in whirling, may be as perfect a Conductor as it can be made, in order to ſupply Electricity as quick as poſſible; and the oppoſite part ſhould be as much a Non-conductor as poſſible, in order that none of the fluid accumulated upon the glaſs, may return back to the rubber; which has been found by experiment to be the caſe, when the rubber is not made in a proper manner. For which reaſon a piece of ſilk is alſo added to the extremity of the leather.—Mr. NAIRNE's rubber conſiſts of ſilk only put over the leather cuſhion, and very little amalgam is uſed with it.

The rubber ſhould be ſupported by a ſpring, by which means it may eaſily ſuit any inequalities that may be found on the ſurface of the glaſs; and by a ſcrew it may be made to preſs harder or ſofter, as occaſion may require. It ſhould alſo be inſulated in whatever manner is moſt convenient;

nient; for whenever insulation is not required, a chain or wire, &c. may be occasionally hung upon it, and thus it may be made to communicate with the earth, or with any other body, at pleasure; whereas, when there is not a contrivance for insulating the rubber, many of the most curious experiments in Electricity cannot be performed with the machine.

We come now to consider the prime Conductor, or first Conductor, which is nothing more than an insulated conducting substance furnished with one or more points at one end, in order to collect the Electricity immediately from the Electric. When the Conductor is of a moderate size, it is usual to make it of hollow brass; but when it is very large, then, on account of the price of the materials, it is made of pasteboard or wood, covered with tin-foil, of tin plates, or even of gilt paper. The Conductor is generally made cylindrical; but let the form be what it will, it should always be made free from points, or sharp edges; and if holes are to be made in it, which on many accounts are very convenient, they should be well round-

ed, and made perfectly ſmooth. Further, that end of the prime Conductor, which is at the greateſt diſtance from the Electric, ought to be made larger than the reſt, as the ſtrongeſt exertion of the electric fluid, in eſcaping from the Conductor, is always at that end.

It has been conſtantly obſerved, that the larger the prime Conductor is, the longer, and denſer ſpark can be drawn from it; and the reaſon of this is, that the quantity of Electricity, diſcharged in a ſpark, is nearly proportional to the ſize of the Conductor; on this account the prime Conductor is now made much larger, than what was formerly uſed. Its ſize, however, may be ſo large, that the diſſipation of the Electricity from its ſurface, may be greater than what the Electric can ſupply; in which caſe ſo large a Conductor would be nothing more than an unwieldy, and diſagreeable incumbrance.

Before we quit the Electrical Machine, it ſhould be obſerved, that, beſides the above-mentioned parts, it is neceſſary to

have a ſtrong frame to ſupport the Electric, the rubber, and the wheel. The prime Conductor ſhould be ſupported by ſtands with pillars of glaſs, or other ſolid Non-conductor, and not by ſilk ſtrings, which admit of continual motion. In ſhort, the machine, the prime Conductor, and any other apparatus actually uſed, ſhould be made to ſtand as ſteady as poſſible, otherwiſe many inconveniences will ariſe.

Beſides the electrical Machine, the Electrician ſhould be provided with glaſs tubes of different ſizes, a pretty large ſtick of ſealing-wax, or a glaſs tube covered with ſealing-wax, for the negative Electricity. He ſhould at leaſt not be without a glaſs tube about three feet long, and one inch and a half in diameter. This tube ſhould be cloſed at one end, and at the other end ſhould have fixed a braſs cap with a ſtop-cock, which is uſeful in caſe it ſhould be required to condenſe or rarefy the air within the tube.

The beſt rubber for a tube of ſmooth glaſs is the rough ſide of black oiled ſilk,

eſpecially

especially when it has ſome amalgam rubbed upon it; but the beſt rubber for a rough glaſs tube, a ſtick of baked wood, ſealing-wax, or ſulphur, is ſoft new flannel.

The inſtruments neceſſary for the accumulation of Electricity, are coated Electrics, among which, glaſs coated with Conductors obtains the principal place. On account of its ſtrength it may be formed into any ſhape, and it will receive a very great charge. The form of the glaſs is immaterial with reſpect to the charge it will contain; its thickneſs only is to be conſidered, for the thinner it is, the higher charge it is capable of receiving; but it is at the ſame time more ſubject to be broken by the force of electric attraction; for this reaſon, therefore, a thin coated jar or plate may be uſed very well by itſelf, and it is very convenient for many experiments; but when large batteries are to be conſtructed, then it is neceſſary to uſe glaſs a little thicker, and care ſhould be taken to have them perfectly well annealed. If a battery be required of no very great power, as containing about eight or nine ſquare feet of coated glaſs, I ſhould recommend to make

uſe of common pint, or half-pint phials, ſuch as Apothecaries uſe. They may be eaſily coated with tin-foil, ſheet-lead, or gilt-paper on the outſide, and braſs-filings on the inſide; they occupy a ſmall ſpace, and, on account of their thinneſs, hold a very good charge. But when a large battery is required, then theſe phials cannot be uſed, for they break very eaſily; and for that purpoſe cylindrical glaſs jars, of about fifteen inches height, and four or five inches in diameter, are the moſt convenient. One large jar anſwers better than ſeveral ſmall ones, becauſe the diſſipation of the electric fluid over the uncoated part is not ſo conſiderable in the former as in the latter caſe. But then, if a large jar breaks, the loſs is much more conſiderable.

When glaſs plates or jars, having a ſufficiently large opening, are to be coated, the beſt method is to coat them with tin-foil on both ſides, which may be fixed upon the glaſs with paſte, varniſh, gum-water, bees-wax, &c.; but in caſe the jars have not an aperture large enough to admit the tin-foil, and an inſtrument to adapt it to the ſurface of

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the glaſs, then braſs filings, ſuch as are ſold by the pin-makers, may be advantageouſly uſed, and they may be ſtuck with gum-water, bees-wax, &c. but not with varniſh, for this is apt to be ſet on fire by the diſcharge, as will appear in the latter part of this work. Care muſt be taken that the coatings do not come very near the mouth of the jar, for that will cauſe the jar to diſcharge itſelf. If the coating is about two inches below the top, it will in general do very well; but there are ſome kinds of glaſs, eſpecially tinged glaſs, that, when coated and charged, have the property of diſcharging themſelves more eaſily than others, even when the coating is five or ſix inches below the edge *. There is another ſort of glaſs, like that of which Florence flaſks are made, which, on account of ſome unvitrified particles in its ſubſtance, is not capable of holding the leaſt charge; on theſe accounts, therefore, whenever a great number of jars

* When a jar diſcharges itſelf, the electric fluid runs from the inſide to the outſide coating over the ſurface of the glaſs, where it leaves an indelible mark all along its path, which is moſtly of a *zig-zag* form.

are to be chosen for a large battery, it is advisable to try some of them first, so that their quality and power may be ascertained.

Electricians have often endeavoured to find some other Electric, which might answer better than glass for this purpose, at least be cheaper; but, except Father Beccaria's method, which may be used very well, I do not find that any remarkable discovery has been made relating to this point.

Father Beccaria took equal quantities of very pure colophonium, and powder of marble sifted exceedingly fine, and kept them in a hot place for a considerable time, where they became perfectly free from moisture; he then mixed them, and melted the composition in a proper vessel over the fire, and when melted poured it upon a table, upon which he had previously stuck a piece of tin-foil, reaching within two or three inches of the edge of the table; this done, he endeavoured with a hot iron to spread the mixture all over the table as equally as possible,

poſſible, and to the thickneſs of one-tenth of an inch; he afterwards coated it with another piece of tin-foil, reaching within about two inches of the edge of this mixture; in ſhort, he coated a plate of this mixture like a plate of glaſs. This coated plate, from what he ſays, ſeems to have had a greater power than a glaſs plate of the ſame dimenſions, even when the weather was not very dry: and, if it is not ſubject to break very eaſily by a ſpontaneous diſcharge, I think it may be very conveniently uſed; for it doth not very readily attract moiſture, and conſequently may hold a charge of Electricity better, and longer, than glaſs: beſides, if broken, it may be repaired by a hot iron; which is not the caſe with glaſs.

When a jar, a battery, or in general a coated Electric, is to be diſcharged, the operator ſhould be provided with an inſtrument called the diſcharging Rod, which conſiſts of a metal rod ſometimes ſtraight, but more commonly bended in the form of a C: they are made alſo of two joints, ſo as to open like a kind of compaſſes. This rod

is furnifhed with metal knobs at its extremities, and has a non-conducting handle, generally of glafs or baked wood, faftened to its middle. When the operator is to ufe this inftrument, he holds it by the handle, and, touching one of the coated fides of the charged Electric with one knob, and approaching the other knob to the other coated fide, or fome conducting fubftance communicating with it, he completes the communication between the two fides, and difcharges the Electric.

The inftruments to meafure the quantity, and afcertain the quality of Electricity, are commonly called *Electrometers*; and they are of four forts, 1ft. the fingle Thread, 2d. the Cork, or Pith-balls, 3d. the Quadrant, and 4th. the difcharging Electrometer *. But a particular defcription of the fame will be found in the third chapter of this work.

* The fecond fort of Electrometer, *i. e.* the cork-balls Electrometer, was invented by Mr. CANTON: the difcharging Electrometer was invented by Mr. LANE; and another, on a different principle, by Mr. KINNERSLEY: and the quadrant Electrometer, which is of lateft invention, is a contrivance of Mr. HENLY.

Befides

Besides the apparatus above described, there are several other instruments useful for various experiments, but these will be described occasionally. The Electrician, however, ought to have by him not only a single coated jar, a single discharging rod, or, in short, only what is necessary to perform the common experiments; but he should provide himself with several plates of glass, with jars of different sizes, with a variety of different instruments of every kind, and even tools for constructing them; in order that he may readily make such new experiments, as his curiosity may induce him to try, or that may be published by other ingenious persons, who are pursuing their researches in this branch of philosophy.

CHAP.

CHAP. II.

The description of some particular electrical Machines.

IN this chapter I shall present the reader with the particular description of some electrical Machines, which, I think, will be very acceptable after the general account of their construction, which has already been given. The first of these is that described by Dr. Priestley, in his History of Electricity *; where a drawing of the same may be seen, and which, on account of its extensive use, may be deservedly called a universal electrical Machine.

The basis of this machine consists of two oblong boards, which are kept in a situation parallel to one another, about four inches asunder, by two small pieces of board properly adapted to that purpose. These boards, when set horizontally upon a table, and there fixed by fastening the lower of them with iron clamps, form the support of two perpendicular pillars of

* Part V. Sec. II.

baked

baked wood, and of the rubber of the machine. One of the pillars, together with the ſpring ſupporting the rubber, ſlides in a groove, which reaches almoſt the whole length of the upper board, and, by means of ſcrews, may be placed at any required diſtance from the other pillar, which is fixed; being let through a mortice in the upper board, and ſtrongly faſtened to the lower. In theſe two pillars are ſeveral holes for the admittance of the ſpindles of different globes, and, as they may be ſituated at any diſtance from one another, they may be adapted to receive not only globes, but alſo cylinders, or ſpheroids, of different ſizes. In this machine, ſays Dr. PRIESTLEY, more than one globe or cylinder may be uſed at once, by fixing them one above the other in the different holes of the pillars; and by adapting to each a proper pulley, they may be whirled all at once, and their power united, in order to increaſe the Electricity *; but in this conſtruction I do not

* When ſeveral globes are uſed at once, and their power is united, it has been found by experiment, that the Electricity does not increaſe in proportion to their number,

not think that different rubbers can be conveniently applied to them all; which is a capital imperfection.

"The rubber consists of a hollow piece "of copper, filled with horse-hair, and "covered with a basil skin. It is supported by a socket, which receives the "cylindrical axis of a round and flat piece "of baked wood, the opposite part of "which is inserted into the socket of a "bent steel spring. These parts are easily "separated, so that the rubber, or the piece "of wood that serves to insulate it, may "be changed at pleasure. The spring "admits of a two-fold alteration of position. It may be either slipped along the "groove, or moved in the contrary direction" (the groove being wider than the screw which fastens the spring), "so "as to give it every desirable position with

number, although it is more than what may be produced by a single globe. However, as the friction, and the difficulty of working the machine, increases in proportion to the number of globes or cylinders, so I think that one good large cylinder is preferable to many of them.

"respect

"respect to the globe or cylinder; and it "is, besides, furnished with a screw, which "makes it press harder or lighter, as the "operator chooses."

The wheel of this machine is fixed to the table; it has several grooves, for admitting more strings than one, in case that two or three globes or cylinders are used at a time; and as it is disengaged from the frame of the machine, the latter may be screwed at different distances from the former, and thus suited to the variable length of the string.

The prime Conductor is of hollow copper, made in the shape of a pear, situated with its neck upwards, and with its bottom or rounder part upon a stand of baked wood; and an arched wire proceeds from its neck, having an open ring at its end, in which some small pointed wires are hung, that by playing lightly upon the Electric, collect the electric fluid from it. This form of prime conductor is, however, very improper.

This machine, notwithſtanding that it has ſeveral imperfections, is yet a very good contrivance; but, except different globes, or cylinders, or ſeveral of thoſe at once, are required to be uſed, I think a great deal of the work may be ſpared, and the machine might be made more ſimple and conciſe.

Next to Dr. PRIESTLEY's machine, I ſhall deſcribe another, which, for its ſimplicity, and conciſeneſs, makes a fine contraſt with the former.

This machine conſiſts of a circular glaſs plate, about one foot diameter, which is turned vertically by a winch fixed to the iron axis that paſſes through its middle; and it is rubbed by four cuſhions, each about two inches long, ſituated at the oppoſite ends of the vertical diameter.

The frame conſiſts of a bottom board, about a foot ſquare, or a foot long and ſix inches broad, which, when the machine is to be uſed, may be faſtened by an iron clamp to the table. Upon this board two other ſlender and ſmaller ones are raiſed, which

which lie parallel to one another, and are faſtened together at their top by a ſmall piece of wood. Theſe upright boards ſupport in their middle the axis of the plate, and to them the rubbers are faſtened.

The Conductor is of hollow braſs, and from its extremities branches are extended, which coming very near the extremity of the glaſs, collect the Electricity from it.

The power of this machine is perhaps more than a perſon would judge by looking at it. It may be objected, that this conſtruction will not eaſily admit of the rubbers being inſulated, nor conſequently be adapted to a great variety of experiments; but at the ſame time it muſt be allowed, that it is very portable, that it is not very liable to be out of order, and that it has a power ſufficiently ſtrong for ſeveral purpoſes; on which account it may be conveniently uſed. Theſe machines have often been made with two parallel glaſs plates, and thoſe of a conſiderable diameter; which plates, turning upon the ſame

axis, are rubbed by eight rubbers.—The ſparks obtained from the conductors of thoſe machines are ſtrong, though not very long; yet an electrical battery may be charged by one of thoſe machines very quick, ſince they accumulate an aſtoniſhing quantity of electric fluid. Their principal imperfections are, the great number of rubbers that the operator muſt keep in proper order, the friction ariſing from them, which renders the turning of the machine rather hard, and laſtly, the plates being ſubject to crack very eaſily.

The machine repreſented in fig. 1. of plate I. has all the principal improvements hitherto made, except that it is not capable of admitting different kinds, or more than one Electric, but which, indeed, it ſeems not to ſtand in need of. The electric power of ſuch a machine, is at leaſt equal to what may be obtained by any other conſtruction; and at the ſame time its ſize, being neither remarkably large, nor at all inconvenient, renders it, I think, the *completeſt machine* hitherto contrived, and may be made of any ſize.

The

The frame of this machine confifts of the bottom board A B C, which, when the machine is to be ufed, is faftened to the table by two iron clamps, one of which appears in the figure near C. Upon the bottom board are perpendicularly raifed two ftrong wooden pillars K L, and A H, which fupport the cylinder, and the wheel. From one of the brafs caps of the cylinder F F, an axle of fteel proceeds, which paffes quite through a hole in the pillar K L, and has on this fide of the pillar a pulley I, fixed upon its fquare extremity. Upon the circumference of this pulley there are three or four grooves, in order to fuit the variable length of the ftring *a b*, which goes round one of them, and round the groove of the wheel D. The other cap of the cylinder has a fmall cavity, which fits the conical extremity of a ftrong fcrew, that proceeds from the pillar H. The wheel D, which is moved by the handle E, turns round a ftrong axle, proceeding from almoft the middle part of the pillar K L.

The rubber G of this machine is on each end two or three inches fhorter than the

cylinder (*i. e.* the cylinder exclufive of the necks), and it is made to rub about one-tenth part of the cylinder's circumference, or rather lefs; it confifts of a thin quilted cufhion of filk, ftuffed with hair, and faftened by filk ftrings upon a piece of wood, which is properly adapted to the furface of the cylinder. And to the lower extremity of the cufhion, or rather of the piece of wood to which the cufhion is tied, a piece of leather is faftened, which is turned over the cufhion, *i. e.* ftands between it and the furface of the cylinder, and to the extremity of which a piece of filk or oiled filk is faftened, which covers almoft all the upper part of the cylinder. Upon this leather, which reaches from the lower to almoft the upper extremity of the cufhion, fome of the above defcribed amalgam is to be worked, fo as to be forced as much as poffible into its fubftance: if mofaic gold is to be tried, then the leather fhould be new, and whereon no other amalgam has been put. This rubber is fupported by two fprings, fcrewed to its back, and from which it may be eafily unfcrewed, when occafion requires it. The two fprings proceed from the wooden cap

cap of a ſtrong glaſs pillar *, perpendicular to the bottom board of the machine. This pillar has a ſquare wooden baſis, that ſlides in two grooves in the bottom board A B C, upon which it is faſtened by a ſcrew. In this manner the glaſs pillar may be faſtened at any required diſtance, and in conſequence the rubber may be made to preſs harder or lighter upon the cylinder. The rubber in this manner is perfectly inſulated; and, when inſulation is not required, a chain with a ſmall hook may be hanged to it, ſo as to have a regular communication with the piece of leather; the chain then falling upon the table, renders the rubber uninſulated.

Fig. 2. repreſents the prime Conductor A B belonging to this machine. This is

* This glaſs pillar, as well as the glaſs feet of inſulating ſtools in general, ſhould be covered with varniſh, or rather with ſealing-wax, otherwiſe they inſulate very imperfectly, on account of the moiſture which they attract from the air, eſpecially in damp weather. It muſt be obſerved, that ſealing-wax diſſolved in ſpirits of wine may be uſed very well for this purpoſe; but to cover a piece of glaſs with ſealing-wax, by rubbing a ſtick of it upon the ſurface of the glaſs when hot, anſwers far better.

of hollow braſs, and is ſupported by two glaſs pillars varniſhed, that by two braſs ſockets are fixed in the board CC. This Conductor receives the electric fluid through the points of the collector L, which are ſet at about half an inch diſtance from the ſurface of the cylinder of the machine.

If the handle E, fig. 1, of the wheel, be turned (and on account of the rubber it ſhould be turned always in the direction of the letters *a b c*) this machine ſtanding in the ſituation that is repreſented in the figure, will give poſitive Electricity, *i. e.* the prime Conductor will be electrified poſitively, or overcharged with electric fluid; for by the action of rubbing, the cylinder pumps, as it were, the fluid from the rubber, and every other body properly connected with it, and gives it to the prime Conductor. But if a negative Electricity be required, then the chain muſt be removed from the rubber and hung to the prime Conductor; for in this caſe the Electricity of the prime Conductor will be communicated to the ground, and the rubber remaining

maining insulated, will appear strongly negative. Another Conductor, equal to the Conductor A B, fig. 2, may be connected with the insulated rubber, and then the operator may obtain as strong negative Electricity from this, as he can positive from the Conductor A B.

I shall, lastly, give a short description of the machine lately contrived by Mr. E. NAIRNE, F. R. S. which is principally adapted for medical Electricity, and for that purpose it answers exceedingly well, as with it any degree of electric power may be used with the utmost facility. Fig. 8. of plate II. represents this machine, the principal parts of which are the glass cylinder and the two Conductors, all lying parallel. The Cylinder, which is generally about 9 inches in diameter, is furnished with wooden caps, and turns in two wooden pieces, which are cemented on the tops of two strong glass pillars B B. These pillars are made fast into the bottom board of the machine, which is fastened to the table by means of a clamp. On the under part of the bottom board grooves are formed, through which the

pieces F F ſlide. Theſe pieces ſupport the Conductors upon the ſtrong glaſs pillars D D; and in order to let the Conductors be placed farther or nearer to the glaſs cylinder, the pieces F F may be moved in or out, and may be ſteadied, by means of the ſcrew nuts L L. The rubber is faſtened to the Conductor R, and it conſiſts of a ſtuffed leather cuſhion, to the under part of which a piece of ſilk is glued, which being turned over the ſurface of the cuſhion, *viz.* between it and the glaſs, goes over the Cylinder, and almoſt reaches the pointed wires which are fixed on the other Conductor, for the purpoſe of collecting the fluid from the Cylinder.

The Conductors are of tin covered with black lacquer, and each contains a coated glaſs jar, and likewiſe a ſmall coated tube or ſmall jar, which are ſeen when the caps N N are removed. A knob O is fixed to each Conductor, to which a chain may be occaſionally ſuſpended, in order to have a poſitive or negative Electricity by communicating one of the Conductors with the earth.

The

The longeſt part of the winch C, by which the Cylinder is turned, is of glaſs.

Thus it appears that every part of this machine is inſulated, *viz.* not only the Conductors with the rubber, but even the glaſs Cylinder and its caps; by which means the electric fluid that is accumulated on the Cylinder is leaſt likely to be diſſipated; which, joined to the excellent workmanſhip and execution of every part, renders this machine very powerful; and I muſt confeſs, that I never ſaw an electrical machine, upon any other principle, have ſo much power as one of this conſtruction, and of equal dimenſions.

To this machine Mr. NAIRNE has adapted ſome flexible conducting joints, a diſcharging electrometer, and ſeveral other inſtruments neceſſary to anſwer every purpoſe of medical Electricity; eſpecially the very ſmall ſhocks may be adminiſtered, by means of the jars inſerted into the Conductors, with great facility, and almoſt to an imperceptible degree. For farther particulars

respecting the construction and use of this excellent machine, and its apparatus, I must refer the reader to Mr. NAIRNE's own description.

CHAP. III.

The particular Description of some other necessary Parts of the electrical Apparatus.

FIG. 4 represents a stand supporting the electrometers D D C C. B is the basis of it, made of common wood. A is a pillar of wax, glass, or baked wood. To the top of the pillar, if it be of wax or glass, a circular piece of wood is fixed; but if the pillar be of baked wood, that may constitute the whole. From this circular piece of wood proceed four arms of glass, or baked wood, suspending at their ends four electrometers, two of which, DD, are silk threads about eight inches long, suspending each a small downy feather at its end,

end. The other two electrometers, C C, are thoſe with very ſmall balls of cork, or of the pith of elder; and they are conſtructed in the following manner:—*a b* is a ſtick of glaſs about ſix inches long, covered with ſealing-wax, and ſhaped at top in a ring: from the lower extremity of this ſtick of glaſs proceed two fine linen threads* *c c*, about five inches long, each ſuſpending a cork or pith-ball *d*, about one-eighth of an inch in diameter. When this electrometer is not electrified, the threads *c c* hang parallel to each other, and the cork-balls are in contact; but when electrified, they repel one another, as repreſented in the figure. The glaſs ſtick *a b* ſerves for an inſulating handle, by which the electrometer may be ſupported, when it is uſed without the ſtand A B.

Another ſpecies of the above electrometer is repreſented in fig. 3; which conſiſts of a linen thread, having at each end a ſmall cork-ball. The electrometer is ſuſpended by the middle of the thread on any

* Theſe threads ſhould be wetted in a weak ſolution of ſalt.

Conductor

Conductor proper for the purpofe, and ferves to fhew the kind and quantity of its Electricity.

Fig. 7 reprefents Mr. HENLY's quadrant electrometer, fixed upon a fmall ftand, from which it may be occafionally feparated, and fixed upon the prime Conductor, or in any other place, at pleafure. This electrometer confifts of a perpendicular ftem, formed at the top like a ball, and furnifhed at its lower end with a brafs ferrule, by which it may be fixed in one of the holes of the prime Conductor, or in its proper ftand, as occafion requires. To the upper part of the ftem, or pillar, a graduated ivory femicircle is fixed, about the middle of which is a brafs arm, which contains a pin, or the fmall axis of the index. The index confifts of a very flender ftick, which reaches from the center of the graduated femicircle to the brafs ferrule, and at its lower extremity is faftened a fmall cork-ball, nicely turned in a lathe. Fr. BECCARIA recommends to inclofe the upper part of the index of this electrometer between two femicircles.

The properest wood, for the purpose of making a pillar and index of this electrometer, is box, and this pillar and index should be well rounded, and made as smooth as possible. When this electrometer is not electrified, the index hangs parallel to the pillar, as in fig. 7; but when it is electrified, the index recedes more or less, according to the quantity of Electricity, from the stem; as represented at E on the prime Conductor, fig. 2.

The main of Mr. LANE's discharging Electrometer, consists in a brass ball about one inch and a half in diameter, screwed to a brass graduated rod, and adapted to a proper frame, so that it may be set at any required distance from the prime Conductor, or the knob of an electric jar. The principal use of this electrometer is to let a jar discharge by itself through any proper circuit, without using any discharging rod, or removing any part of the apparatus; and to give shocks nearly of the same strength. Suppose, for instance, that the above-mentioned brass ball be set at half an inch distance from the prime Conductor, and that a coated

coated jar be ſituated ſo as to touch the prime Conductor with its knob, and to have its outſide coating communicating with the above-mentioned braſs ball. Now it is evident that the circuit, from the outſide to the inſide of the jar, is interrupted only between the prime Conductor and the braſs ball, which lie half an inch aſunder; therefore, when the jar is charging, and the charge is become ſo high as to ſtrike through half an inch of air, the jar will diſcharge itſelf, and, by keeping the braſs ball at the ſame diſtance from the prime Conductor, and charging the jar ſucceſſively, the ſhocks will be of the ſame ſtrength.

This electrometer is ſubject to an inconvenience; which is, that the ſurface of the braſs ball is ſometimes deprived of its ſmoothneſs by the force of the exploſion; in which caſe it is neceſſary to poliſh it again, otherwiſe the inſtrument is uſeleſs; this, however, never happens when ſmall ſhocks are uſed. An electrometer of this kind, though not exactly like the original one, is now commonly uſed by the practitioners of medical electricity, and is delineated in fig. 6, of Plate II.

It

It consists of a glass arm D, which proceeds from the wire of the jar F, and to the extremity E of which a spring socket is cemented, through which a wire passes, which is furnished with a knob B, towards the knob A of the jar, and with an open ring C at its other extremity. Now, as this wire may be slid backwards and forwards, the knob B may be put at any required distance from the knob A, as far as the construction of the instrument will allow. The wire BC is generally marked with divisions, which shew the distance of the two knobs, when the wire is so situated, as that the required division coincides with the edge of the spring socket; as, for instance, one-tenth, or one quarter of an inch, &c. When the jar F is set against the prime Conductor G, as represented in the figure, suppose that the ball B is set at the distance of $\frac{1}{10}$ of an inch from the ball A, and that a wire be fixed from the electrometer's ring to the outside coating of the jar, as shewn by the dotted line CK; then, when the machine is put in motion, the discharge of the jar, as soon as this becomes sufficiently charged, will be made between the knobs AB, and through the

the wire CK; and it is evident that theſe diſcharges will be of the ſame ſtrength, as long as the diſtance between AB remains the ſame.

Fig. 5 of Plate I. repreſents Mr. HENLY's univerſal diſcharger, which is of a very extenſive uſe, and is compoſed of the following parts:—A is a flat board fifteen inches long, four inches broad, and one thick, or thereabouts, which forms the baſis of the inſtrument. BB are two glaſs pillars, cemented in two holes upon the board A, and furniſhed at their top with braſs caps, each of which has a turning joint, and ſupports a ſpring tube, through which the wire DC ſlides: each of theſe caps is compoſed of three pieces of braſs, connected ſo, that the wire DC, beſides its ſliding through the ſocket, has two other motions, *viz.* an horizontal and a vertical one. Each of the wires DC, DC, is furniſhed with an open ring at one end, and at the other end has a braſs ball D, which, by a ſhort ſpring ſocket, is ſlipt upon its pointed extremity, and may be removed from it at pleaſure. E is a ſtrong circular piece of wood, five inches

in

in diameter, having, on its ſurface, a ſlip of ivory inlaid, and furniſhed with a ſtrong cylindrical foot, which fits the cavity of the ſocket F, which is faſtened in the middle of the bottom board, and has a ſcrew G, which ſerves to faſten the foot of the circular board E at any required height. H is a ſmall preſs belonging to this inſtrument; it conſiſts of two oblong pieces of board, which may be preſſed againſt each other by means of two ſcrews *a a*: the lower of theſe boards has a cylindrical foot equal to the foot of the circular board E. When this preſs is to be uſed, it is fixed into the ſocket F, in the place of the circular board E, which muſt, in that caſe, be removed.

Fig. 11 is an electric jar, coated with tin-foil on the inſide and outſide, within three inches of the top of the cylindrical part of the glaſs, having a wire with a round braſs knob A at its extremity. This wire paſſes through the cork * D, that ſtops the mouth of the jar, and, at its lower

* When corks are uſed to ſtop electric jars, they ſhould be made very dry, and dipped in melted bees-wax, or varniſhed.

end,

end, is bent ſo as to touch the inſide coating in ſeveral places.

Fig. 10 repreſents a battery compoſed of ſixteen jars, coated in the inſide and outſide with tin-foil, which all together contain about twelve feet of coated glaſs. About the middle of each of theſe jars is a cork that ſuſtains a wire, which at the top is faſtened round, or ſoldered to the wire E, knobbed at each end, which connects the inſide coatings of four jars; and by the wires FFF the inſide coatings of all the ſixteen jars are connected together. Each of the wires F has a ring at one end, through which one of the wires E paſſes, and at the other end has a braſs knob. If the whole force of the battery be not required, one, two, or three rows of jars may be uſed at pleaſure; for as each of the wires FFF is moveable round the wire E, which paſſes through its ring, and reſts upon the next wire E, it may be eaſily removed from that, and turned upon the contrary wire E; and thus the communication between one row of jars and another may be diſcontinued at pleaſure. See the figure.

The ſquare box that contains theſe jars is of wood lined at the bottom with ſheet-lead or tin-foil, and has two handles on two oppoſite ſides, by which it may be eaſily removed. In one ſide of the box is a hole, through which an iron hook B paſſes, which communicates with the metallic lining of the box, and conſequently with the outſide coating of all the jars. To this hook is faſtened a wire, the other end of which is connected with the diſcharging-rod.

The diſcharging-rod conſiſts of a glaſs handle A, and two curved wires BB, which move by a joint C, fixed to the braſs cap of the glaſs handle A. The wires BB are pointed, and the points enter the knobs DD, to which they are ſcrewed, and may be unſcrewed from them at pleaſure. By this conſtruction we have the opportunity of uſing the balls or the points, as occaſion requires; and as the wires are moveable by the joint C, they may be adapted to ſmaller or larger jars at pleaſure.

The battery, reprefented in the plate, is a fmall one in comparifon to thofe now frequently ufed, and much too weak for the purpofe of fome experiments, hereafter to be defcribed. But I thought it fufficient to give an idea of its conftruction; and, when a large battery is to be conftructed, I would recommend rather to make two, three, or more fmall ones, as reprefented in the plate, than a fingle large battery, which is heavy, and, on feveral accounts, inconvenient. The force of feveral fmall batteries may be eafily united by a wire or a chain, and thus they may be made to act like a large one.

F in fig. 2. is a circular brafs plate hung on the prime Conductor by a chain, and refting in an horizontal pofition. Underneath this, there is another plate P parallel, and equal to the former (but it would be better if it were a little larger), which is fupported by a ftand H of brafs, having alfo a focket to receive the foot of the plate, and a fcrew G to fix it at different heights.

D in fig. 2. is a fly made of ſmall braſs wires, fixed in a cap of braſs alſo; which is to be put upon the pointed wire K, that is ſcrewed to the prime conductor, upon which it muſt ſtand in equilibrio, like the needle of a compaſs. The other ends *a*, *b*, *c*, *d* of the wires are pointed, and bent all one way.

N. B. Whenever hereafter I mention the prime Conductor, I mean the prime Conductor naked, that is, without the parallel braſs plates FP, without the fly D and its ſupporting pin K, without the electrometers E, and even without the knobbed rod IB, which is ſcrewed to it occaſionally; except the contrary is expreſſed.

It is highly requiſite for an Electrician to have by him ſeveral inſulating ſtools, or ſtands; they being very neceſſary for ſeveral experiments. The beſt materials to conſtruct theſe are glaſs covered with ſealing-wax. Baked wood may alſo be uſed*. A large

* The wood ſhould be baked very well, even till it becomes quite brown, it then being in the beſt ſtate for

 inſulation;

large ſtool, proper to inſulate a chair upon, or two or three perſons ſtanding, may be made with a ſtrong board, about two feet and a half ſquare, and may be ſupported by four feet of glaſs, about eight inches long. But ſmall ſtands are better made with one foot or pillar, and all of baked wood or glaſs, without any conducting ſubſtance in their conſtruction. Wine-glaſſes, either varniſhed, or in part covered with ſealing-wax, anſwer this purpoſe very well.

inſulation; and to defend it from moiſture, it muſt be varniſhed as ſoon as it comes out of the oven, or elſe boiled in linſeed oil: but in this caſe, after boiling, it ſhould be made hot again, and then it is fit for uſe.

CHAP.

CHAP. IV.

Practical Rules concerning the Use of the electrical Apparatus, and the performing of Experiments.

IT often happens that young Electricians are at a loſs to aſſign the reaſon, why ſome experiments do not ſucceed with them, as deſcribed in the Treatiſes on Electricity. Sometimes they are in poſſeſſion of very good inſtruments, but, by reaſon of ſome circumſtance or other unattended to, they are quite uſeleſs in their hands. This indeed can be remedied by nothing but practice, and it is by long uſe, that the Electrician, as well as the Practitioner in any art or ſcience, becomes ſo good an Operator, as to uſe his inſtruments to the beſt advantage. A few rules are however very neceſſary, to guide him in his operations; and although theſe alone are inſufficient to make a perſon a complete practical Electrician, yet, when accompanied with the actual management of the apparatus, they fa-

cilitate the uſe of it, and render the performance of the experiments more accurate and expeditious.

The firſt thing that the young Electrician ſhould obſerve, is, the preſervation, and care, of his inſtruments. The electrical machine, the coated jars, and in ſhort every part of the electrical apparatus, ſhould be kept clean, and as free as poſſible from duſt, and moiſture.

When the weather is clear, and the air dry, eſpecially in ſerene and froſty weather, the electrical machine will always work well. But when the weather is very hot, the electrical machine is not ſo powerful: nor in damp weather, except it be brought into a warm room; and the cylinder, the ſtands, the jars, &c. be made thoroughly dry.

Before the machine be uſed, the cylinder ſhould be firſt wiped very clean with a ſoft linen cloth, that is dry, clean, and warm; and afterwards with a clean hot flannel, or an old ſilk handkerchief; this done, if the winch

winch be turned, when the prime Conductor, and other inſtruments, are removed from the electrical machine, and the knuckle be held at a little diſtance from the ſurface of the cylinder, it will be ſoon perceived that the electric fluid comes like a wind from the cylinder to the knuckle, and, if the motion be a little continued, ſparks, and crackling will ſoon follow. This indicates that the machine is in good order, and the Electrician may proceed to perform his experiments. But if, when the winch is turned for ſome time, no wind be felt upon the knuckle, then the fault is, very likely, in the rubber; and to remedy that, uſe the following directions:—By unſcrewing the ſcrews on the back of the rubber, remove it from its glaſs pillar, and keep it a little near the fire, ſo that its ſilk part may be dried; take now a dry piece of mutton-ſuet, or a little tallow from a candle, and juſt paſs it over the leather of the rubber, then ſpread a ſmall quantity of the above-deſcribed amalgam over it, and force it as much as poſſible into the leather. This done, replace the rubber upon the glaſs pillar; let the glaſs cylinder be wiped

once more, and then the machine is fit for uſe. In Mr. NAIRNE's machine no amalgam is put upon the rubber; but whilſt the clean rubber is on, and the cylinder turning, a piece of leather with ſome amalgam ſpread on it is applied for a few ſeconds to the under part of the cylinder, the doing of which will bring a ſufficient quantity of amalgam to the rubber.

Sometimes the machine will not work well, becauſe the rubber is not ſufficiently ſupplied with electric fluid; which happens when the table upon which the machine ſtands, and to which the chain of the rubber is connected, is very dry, and conſequently in a bad conducting ſtate. Even the floor and the walls of the room are, in very dry weather, bad Conductors, and they cannot ſupply the rubber ſufficiently. In this caſe, the beſt expedient is, to connect the chain of the rubber, by means of a long wire, with ſome moiſt ground, a piece of water, or with the iron-work of the water pump; by which means the rubber will be ſupplied with as much electric fluid as is required.

It

It muſt be alſo remarked, that when the cylinder is very hot, as above 110°, it will not act well.

When a ſufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work very well, then, inſtead of putting more amalgam, it will be ſufficient to take the rubber off, and to ſcrape a little, that which is already upon the leather.

It will be often obſerved, that the cylinder, after being uſed ſome time, contracts ſome black ſpots, occaſioned by the amalgam, or ſome foulneſs of the rubber, which grow continually larger, and greatly obſtruct its electric power. Theſe ſpots muſt be carefully taken off, and the cylinder muſt be frequently wiped, in order to prevent its contracting them.

In charging electric jars in general, it muſt be obſerved, that not every machine will charge them equally high. That machine, whoſe electric power is the ſtrongeſt, will always charge the jars higheſt. If the

the coated jars, before they are uſed, be made a little warm, they will receive, and hold the charge the better.

If ſeveral jars are connected together, among which there is one, that is apt to diſcharge itſelf very ſoon, then the other jars will alſo ſoon be diſcharged with that; although they may be capable of holding a very great charge by themſelves. When electric jars are to be diſcharged, the Electrician muſt be cautious leſt, by ſome circumſtance not adverted to, the ſhock ſhould paſs through any part of his body; for an unexpected ſhock, even when not very ſtrong, may occaſion ſeveral diſagreeable accidents. In making the diſcharge, care muſt be taken that the diſcharging-rod be not placed on the thinneſt part of the glaſs, for that may cauſe the burſting of the jar.

When large batteries are diſcharged, jars will be often found broken in it, which burſt at the time of the diſcharge. To remedy this inconvenience, Mr. NAIRNE ſays he has found a very effectual method; which is, never to diſcharge the battery through a

good

good Conductor, except the circuit be at least five feet long. Mr. NAIRNE adds, that ever ſince he made uſe of this precaution, he has diſcharged a very large battery near a hundred times, without ever breaking a ſingle jar, whereas before he was continually breaking them. But here it muſt be conſidered, that the length of the circuit weakens the force of the ſhock proportionably; the higheſt degree of which is in many experiments required.

When a coated phial is cracked, either by a ſpontaneous diſcharge, or by any other accident, I remove the outſide coating from the fractured part, and then make it moderately hot by holding it to the flame of a candle, and whilſt it remains hot, I apply burning ſealing-wax to the part, ſo as to cover the fracture entirely: taking care that the thickneſs of the wax is rather more than the thickneſs of the glaſs. Laſtly, I cover all the ſealing-wax, and alſo part of the ſurface of the glaſs beyond it, with a compoſition made with four parts of bees-wax, one of roſin, one of turpentine, and a very little oil of olives; which compoſi-

tion

tion I ſpread upon a piece of oiled ſilk, and apply it in the manner of a plaiſter. With this method I have repaired ſeveral broken phials ſo effectually, that after being frequently charged, they were at laſt broken by a ſpontaneous diſcharge, but in a different part of the glaſs *.

It is adviſeable, when a jar, and eſpecially a battery, has been diſcharged, not to touch its wires with the hand, before the diſcharging-rod be applied to its ſides a ſecond, and even a third time; as there generally remains a reſiduum of the charge †, which is ſometimes very conſiderable.

* Here it is proper to remark, that when jars, or glaſs in general, that is coated for the purpoſe of charging and diſcharging, is in any manner covered with cement or ſealing-wax, it breaks more eaſily by a ſpontaneous diſcharge; and it is very remarkable, that the fracture generally lies on the limits of the cement.

† This reſiduum is in great meaſure occaſioned by the Electricity, that, when the jar is charging, ſpreads itſelf over the uncoated part of the glaſs near the coating, which will not be diſcharged at firſt, but gradually returns to the coating after the firſt diſcharge.

When

When any experiment is to be performed, which requires but a ſmall part of the apparatus, the remaining part of it ſhould be placed at a diſtance from the machine, the prime Conductor, and even from the table, if that be not very large. Candles, particularly, ſhould be placed at a conſiderable diſtance from the prime Conductor, for the effluvia of their flames carry off much of the electric fluid.

Laſtly, the young Electrician ſhould be cautioned not to depend on firſt appearances in Electricity. A new phenomenon may juſtly excite his curioſity: it is laudable to remark it, and to purſue the hint; but at the ſame time even the doubtful aſſertion of a new fact ſhould never be made, till after a number of ſimilar and concurring experiments. Electricity is a ſcience that often deceives the ſenſes, and the moſt experienced Electrician frequently finds himſelf miſtaken in things, which perhaps he may have before conſidered as the moſt certain.

CHAP.

CHAP. V.

Experiments concerning electric Attraction and Repulsion.

Experiment I.

The electrified Cork-ball Electrometer.

WHEN the electrical machine is put in order, and the prime Conductor is set so, that the points of the collector are about half an inch from the surface of the cylinder, fix at the end of the prime Conductor the knobbed rod IB fig, 2. and hang on it the electrometer with the cork-balls fig. 3. The balls will now touch one another, the threads hanging perpendicularly, and parallel to each other. But if the cylinder of the machine be whirled by turning the winch E, then the cork balls will repel one another, and more or less, according as the Electricity is more or less powerful.

In this experiment, the glaſs cylinder extracting the electric fluid from the rubber, throws it upon the pointed wires of the collector, and in conſequence upon the prime Conductor, and the electrometer; which are all connected together: and as bodies overcharged with electric fluid will always repel each other, ſo the cork-balls muſt repel each other.

If the electrometer be hung to a prime Conductor negatively electrified, *i. e.* connected with the inſulated rubber of the machine, the cork-balls will alſo repel each other; for bodies, undercharged, will repel each other, as well as bodies overcharged with electric fluid.

If, in this ſtate of repulſion, the prime Conductor be touched with ſome conducting ſubſtance not inſulated, the cork-balls will immediately come together; for the electric fluid ſuperinduced upon the prime Conductor, and the electrometer communicating with it, will be carried away to the ground by that conducting body; ſo that in this caſe the prime Conductor can never be over-

overcharged: nor can it be undercharged, if connected with the rubber; for its deficiency of fluid is ſupplied through that conducting body, with which it has been touched. But if, inſtead of the conducting ſubſtance, the prime Conductor be touched with an electric, as for inſtance a ſtick of ſealing-wax, a piece of glaſs, &c. then the cork-balls will continue to repel each other; becauſe the electric fluid cannot be conducted through that electric: hence we have an eaſy method of determining what bodies are Conductors, and what electrics*.

This electrical repulſion is alſo ſhewn by the quadrant electrometer, with a large downy feather, or the like; for if theſe be connected with the prime Conductor, and the winch be turned, the electrometer will raiſe its index, and the feather, by the divergency of its down, will appear ſwelled in a beautiful manner.

* This method in groſs will do very well; but when the conducting power of fluids or ſome other bodies, and the degree of that power, is to be aſcertained, then recourſe muſt be had to other means, more nice and accurate.

EXPERIMENT II.

Attraction and Repulsion of light Bodies.

Connect with the prime Conductor the two parallel brass plates F, P, as represented in fig. 2. at about three inches distance from one another, and upon the lower plate put any kind of light bodies, as bran, bits of paper, bits of leaf-gold, &c.; then work the machine, and the light bodies will soon move between the two plates, leaping alternately from one to the other with great velocity. If, instead of bran, or irregular pieces of other matter, small figures of men or other things cut in paper, and painted, be put upon the plate, they will generally move in an erect position, but will sometimes leap one upon another, or exhibit different postures, so as to afford a pleasing spectacle to an observing company.

In this experiment, both the attraction and repulsion of Electricity are observed at the same time: for when the upper plate

F, which communicates with the prime Conductor, is electrified, the ſmall bodies placed upon the lower plate, together with that plate, by being within the ſphere of action of the electrified upper plate, become actually poſſeſſed of the contrary Electricity, leaving their proper quantity of fluid in the lower plate, or the other conducting bodies, that communicate with it. But bodies differently electrified attract each other; therefore the plate F attracts thoſe light bodies. Now, as ſoon as theſe bodies touch the plate F, they become inſtantly poſſeſſed of the ſame Electricity with the plate, and will therefore be immediately repelled to the lower plate, which is actually electrified with the contrary Electricity, and by touching the light bodies, aſſiſts in repelling them again to the upper plate; and thus the plates continue to act upon the light bodies alternately.

That the light bodies cannot be attracted by the upper plate, except they become firſt poſſeſſed of a contrary Electricity, may be obſerved as follows:—Put the ſaid light bodies upon a clean, and dry pane of glaſs; then

then take off the braſs plate P, with its ſtand G, and in its ſtead put the pane of glaſs, holding it by one corner; this done, let the wheel of the machine be turned, and you will ſee that the light bodies are not attracted by the braſs plate F; for in this caſe they have no opportunity of parting with their proper quantity of fluid, and conſequently cannot acquire the contrary Electricity. But if to the under ſide of the pane of glaſs, on which the light bodies are placed, a finger or any other Conductor be preſented, the light bodies will be inſtantly attracted by the plate F, and will leap between the glaſs and plate, in the ſame manner as between the two plates; for theſe bodies now depoſit their fluid upon the upper ſurface of the glaſs plate, whilſt the under ſurface depoſits its fluid upon the finger, or other Conductor, that has been brought near it*. If this experiment be

* If the above experiment be made with a prime Conductor negatively electrified, the effect will be the ſame, only the Electricities of the plates are reverſed; *i. e.* the upper plate is electrified negatively, and the under plate, by being in the atmoſphere of the upper one, is poſitively electrified.

continued, the glaſs will ſoon be charged *.

Experiment III.

The Flying-feather, or Shuttle-cock.

The phenomena of electric attraction and repulſion may be repreſented alſo with a glaſs tube, or a charged bottle, and ſome of them in a manner more ſatisfactory than with the machine.

Take a glaſs tube (whether ſmooth, or rough, is not material), and after having rubbed it, let a ſmall light feather be let out of your fingers at the diſtance of about eight or nine inches from it. This feather will be immediately attracted by the tube, and will ſtick very cloſe to its ſurface for a few ſeconds, and ſometimes longer; after which time it will be repelled, and if the tube be kept under it, the feather will continue floating in the air at a conſider-

* Electric attraction and repulſion takes place alſo within a partial vacuum, ſuch as is made by means of common air-pumps.

able

able diſtance from the tube, without coming near it again, except it firſt touches ſome conducting ſubſtance; and if you manage the tube dexterouſly, you may drive the feather through the air of a room at your pleaſure.

The reaſon of this experiment is obvious; for when the feather is electrified, it cannot approach the tube again, except it firſt touches ſome conducting body, becauſe it cannot part with its Electricity when floating in the air, and therefore cannot acquire a contrary Electricity: conſequently it muſt remain in a ſtate incapable of being again attracted by the excited tube.

If it be aſked, Why, when the feather is at firſt attracted by the tube, it ſticks for ſo conſiderable a time to its ſurface before it is repelled; the anſwer is, That the feather being an electric, requireth ſome time before it acquires any conſiderable quantity of Electricity.

There is a remarkable circumſtance attending this experiment, which is, that if

the feather be kept at a diſtance from the tube by the force of electric repulſion, it always preſents the ſame part towards the tube:—You may move the excited tube about the feather very ſwiftly, and yet the ſame ſide of the feather will always be preſented to the tube. The reaſon of this phenomenon is, that the equilibrium of the electric fluid in the parts of the feather, being once diſturbed, cannot eaſily be reſtored; becauſe the feather is an electric, or at leaſt a very bad Conductor. When the feather has acquired a quantity of Electricity from the tube, it is plain, that by the action of the excited tube, that ſuperinduced Electricity will be in the greateſt part forced on that ſide of the feather which happens to be at firſt the fartheſt from the tube; hence that part will always afterward be repelled the fartheſt.

This experiment may be agreeably varied in the following manner:—A perſon may hold in his hand an excited tube of ſmooth glaſs, and another perſon may hold an excited rough glaſs tube, a ſtick of ſealing-wax, or in ſhort another electric

negatively

negatively electrified, at about one foot and a half distance from the smooth glass tube: a feather now may be let go between these two differently-excited electrics, and it will leap alternately from one electric to the other; and the two persons will seem to drive a shuttle-cock from one to the other, by the force of electricity.

EXPERIMENT IV.

The small insulated Body.

Tie a small body, as for instance a light piece of cork, to a silk thread about eight inches long, and holding the thread by its end, let the small body hang at the distance of about eight inches from the side of the prime Conductor electrified. This small body, if the electrization of the Conductor is not strong, will not be attracted; for, being insulated, it cannot, by depositing its fluid upon, or receiving it from, another body (when the prime Conductor is electrified negatively), become contrarily electrified. But if a finger or any conducting substance be presented to

that ſide of the ſmall body which is fartheſt from the prime Conductor, then the ſmall body will immediately move toward the prime Conductor; for it has depoſited its own fluid upon, or acquired ſome (in caſe the Conductor is negatively electrified) from the body preſented to it; and when this body has touched the prime Conductor, it will be inſtantly repelled from it, on account of the repulſion exiſting between bodies poſſeſſed of the ſame kind of Electricity.

Indeed, if this inſulated body be very near to the prime Conductor, or the prime Conductor ſtrongly electrified, then the ſmall body will be attracted without preſenting to it any conducting ſubſtance; but in this caſe its natural quantity of electric fluid will be either repelled into the contiguous air, or crowded on that part of the body which is fartheſt from the prime Conductor, when the Conductor is electrified *poſitively*; but if it be electrified *negatively*, then the additional quantity of fluid, neceſſary to render the ſmall body overcharged, will be acquired from the air, or the

the natural fluid belonging to that body will be all crowded on that ſide of it, which is neareſt to the prime Conductor.

If this ſmall body, inſtead of the ſilk, be ſuſpended by a linen thread, it will be attracted at a much greater diſtance, than in the other caſe; for now the electric fluid will be eaſily conducted by the thread, paſſing upwards, or downwards, according as the prime Conductor is electrified, *viz.* negatively or poſitively.

EXPERIMENT V.

The electric Well.

Place upon an electric ſtool a metal quart mug, or ſome other conducting body nearly of the ſame form and dimenſion; then tie a ſhort cork-ball electrometer, of the kind repreſented fig. 3 *, at the end of a ſilk thread proceeding from the cieling of the room, or from any other proper ſupport,

* Inſtead of the electrometer, there may be uſed any other kind of ſmall conducting body; but that ſeems beſt adapted to ſuch experiments.

ſo

ſo that the electrometer may be ſuſpended within the mug, and no part of it may be above the mouth; this done, electrify the mug, by giving it a ſpark with an excited electric or otherwiſe, and you will ſee that the electrometer, whilſt it remains in that inſulated ſituation, even if it be made to touch the ſides of the mug, is not attracted by it, nor does it acquire any Electricity; but if, whilſt it ſtands ſuſpended within the mug, a Conductor, ſtanding out of the mug, be made to communicate with, or only preſented to it, then the electrometer acquires an Electricity contrary to that of the mug, and a quantity of it, which is proportionable to the body with which it has been made to communicate; and it is then immediately attracted by the mug.

The reaſon why in this experiment the electrometer contracts no Electricity whilſt ſuſpended intirely within the cavity of the mug, is, becauſe the Electricity of the mug acts upon the electrometer on all ſides, and this has no opportunity of parting with its fluid, when the mug is electrified poſitively; nor

nor of receiving any, when the mug is electrified negatively. But, as ſoon as any Conductor communicates with it, the electrometer becomes immediately poſſeſſed of the Electricity contrary to that of the mug; for if the mug be electrified poſitively, the fluid belonging to the electrometer will be repelled to that body, which communicates with it; and which, being out of the mug, cannot be affected by its Electricity; and if the mug be electrified negatively, it will attract the fluid of the electrometer, which actually receives an additional quantity of it from that conducting body, with which it communicates. The electrometer therefore, becoming always poſſeſſed of a contrary Electricity, muſt neceſſarily be attracted.

If, by raiſing the ſilk thread a little, part of the electrometer, *i. e.* of its linen threads, be lifted juſt above the mouth of the mug, the balls will be immediately attracted; for then, by the action of the Electricity of the mug, it will acquire a contrary Electricity by giving to, or receiving the electric fluid from, the air above the cavity of the mug.

It

It has been ſuppoſed by ſome, that the electrometer in the above experiment (or any other ſmall inſulated body), hanging in the cavity of an electrified veſſel, or the like, is not attracted by the ſides of the veſſel, becauſe the attraction of Electricity, being as the ſquares of the diſtances inverſely, cannot affect the electrometer one way more than another; it being demonſtrable, that, if to every point of a ſpherical concave ſurface, equal centripetal forces are directed, decreaſing as the ſquares of the diſtances from theſe points, a ſmall body ſituated any where within that ſurface, would remain there, without being attracted one way more than another *.

But to this it may be replied, that the demonſtration of the above-mentioned propoſition, if it is applicable to ſpherical, or cylindrical concave ſurfaces, cannot, however, be applied to every kind of irregular cavities, with which (if they exceed not a certain ſize) the above experiment ſucceeds as well, as with the cylindrical cavity of the mug.

* NEWTON's Principia, book I. prop. LXX.

In

In ſhort, in this experiment, when the mug is electrified poſitively, it is ſuppoſed, I. That the ſuperinduced fluid, taking its place upon the external ſurface, occaſions the contiguous air to depoſit its fluid upon a ſubſequent quantity of air, and this overcharged air occaſions a contiguous circle, or quantity of air, to depoſit its fluid upon its ſubſequent or next adjacent circle, and ſo on. II. That none of the ſuperinduced fluid can exiſt upon the internal ſurface of the mug, and therefore inſulated bodies, intirely ſuſpended therein, can acquire no Electricity, becauſe the internal air has no opportunity of parting with its own fluid, except a ſmall quantity about the mouth of the mug, where, accordingly, a little Electricity is obſervable. When the mug is electrified negatively, then it is ſuppoſed, I. That the deficiency of fluid in the mug is only on its external ſurface; for the air, contiguous to this ſurface, by acquiring an additional quantity of electric fluid from the next ſtratum of air, may become electrified poſitively. II. That the internal ſurface of the mug is not undercharged, becauſe its contiguous air, being ſurrounded

by

by the mug, cannot become overcharged, by acquiring an additional quantity of fluid, except a ſmall quantity towards the mouth of the mug, where, accordingly, a little Electricity is obſervable.

Experiment VI.

To diſtinguiſh the Quality of Electricity in electrified Bodies.

Before we proceed further, it is neceſſary that we ſhould deſcribe ſome practical method of diſtinguſhing the quality of the Electricity in an electrified body, which is abſolutely neceſſary for the right performance of the enſuing experiments. To do this, different methods may be followed, which however are all founded, either upon the electric attraction, and repulſion, or upon the different appearances of the electric light. To find out the quality of Electricity by the different appearances of its light, is a very convenient, and ſure method; but the phenomena of attraction and repulſion, afford one much more general, and eaſy; for ſometimes the quantity of Electricity to be obſerved is ſo very ſmall,

ſmall, that it will give no light, though it may be ſtill capable of attracting or repelling.

The general method to prove whether the electricity of a body, electrified either by excitation, or communication, is negative, or poſitive, is to bring it pretty near to an electrified electrometer D or C fig. 4, and obſerve whether the body attracts or repels it; for if the electrometer be electrified poſitively, and the electrified body repels it, then you may conclude that the body is alſo electrified poſitively; becauſe bodies, poſſeſſed of the ſame kind of Electricity, repel each other; but if the body preſented attracts the Electrometer, then it muſt be electrified negatively, becauſe there is no electric attraction between bodies, unleſs they are differently electrified; and as the electrometer is known to be electrified poſitively, the body is conſequently electrified negatively.

This may be alſo done by electrifying the electrometer negatively; but then the effects are juſt the contrary, *i. e.* the electrified

fied body, if negative, will repel the electrometer, and if poſitive, will attract it.

In this experiment, however, it muſt be obſerved, that, if the Electricity of the electrified body is much ſtronger than that of the electrometer, or the Electricity of the latter ſtronger than that of the former, and the electrified body be brought very near the electrometer, then they will attract one another, notwithſtanding they are poſſeſſed of the ſame kind of Electricity. Suppoſe, for inſtance, that one of the electrometers C is poſitively electrified, ſo that its cork-balls may diverge about half an inch, and a glaſs tube ſtrongly excited be brought near it; when this tube is a foot diſtant, or more, the electrometer will be a little repelled by it; but if the tube be brought nearer, the cork-balls, that before diverged half an inch, will now converge till they are in contact, and appear, as they actually are, unelectrified; becauſe the action of the excited tube has repelled their ſuperfluous fluid through the threads up to the remoteſt part of the electrometer. If the tube be preſented ſtill nearer, the balls

2 will

will then be attracted by it, because the ſtronger Electricity of the tube repels not only their ſuperinduced, but alſo their natural quantity of fluid up the threads, &c. and therefore the balls, becoming negatively electrified, muſt neceſſarily be attracted by the tube.

Upon this principle an electrometer may be electrified negatively by means of an electric poſitively excited; or, on the contrary, it may be electrified poſitively by an electric poſſeſſed of the negative Electricity. Take, for inſtance, a glaſs tube excited poſitively, and bring it within ſix or ſeven inches under the balls of one of the abovefaid electrometers; in which caſe the balls of the electrometer will diverge, becauſe their natural quantity of electric fluid has been driven from them to the upper part of the threads by the action of the tube poſitively excited; ſo that the balls in reality diverge with negative Electricity. Now, in this ſtate touch the upper part of the threads of the electrometer with your finger, which will take off ſome of the electric fluid natural to the electrometer;

after which remove the finger, and immediately after remove the glaſs tube, and the electrometer will remain electrified negatively, becauſe the excited glaſs tube did not impart any electric fluid to the electrometer, but only diſturbed the equilibrium of the natural quantity of electric fluid, which belonged to it, and part of which eſcaped through the finger that touched the electrometer, and which did conſequently remain in a negative ſtate.—After the like manner the electrometer may be electrified poſitively, by means of a body poſſeſſed of negative Electricity.

But ſhould a more preciſe method than the above be required, to determine the quality of the Electricity of an electrified body, the following may be uſed:—Firſt, electrify one of the electrometers C, placed upon the ſtand fig. 4, either poſitively, or negatively, at pleaſure: touch it, for inſtance, with an excited glaſs tube, ſo that its balls may repel, and ſtand about two inches diſtant from one another; then touch the other electrometer G with the electrified body, that you deſire to examine, ſo that

that it may be poſſeſſed of the ſame degree of Electricity: Laſtly, take either of the two electrometers by the top of the glaſs handle *a*, diſengage it from the arm of the ſtand, and bring it near the other electrometer; if then the balls of one electrometer repel thoſe of the other, you may conclude that they are poſſeſſed of the ſame kind of Electricity; but if they attract each other, you may conclude that they were electrified with contrary Electricities; and as you know the Electricity of that electrometer, which was firſt electrified, you will of courſe know the electricity of the other electrometer, *i. e.* of the electrified body, with which it was touched.

The above experiment may be alſo made with the ſingle-thread electrometers; for if they are brought near to one another, when their feathers are electrified, they will, if poſſeſſed of the ſame Electricity, repel, or if poſſeſſed of contrary Electricities, attract each other.

Experiment VII.

The insulated metallic Rod.

Insulate in an horizontal position a metallic rod about two feet long, having blunt ends, and to one of its ends suspend an electrometer, like that represented fig. 3; then bring within three or four inches distance of its other end an excited glass tube. On the approach of the tube, the balls of the electrometer will open, and if you present towards them a body positively electrified, you will perceive that they diverge with positive Electricity. If the tube be removed, the balls come together again, and no Electricity remains in them, or in the metallic rod. But if while the tube is near one end of the rod, and the balls diverge with positive Electricity, the other end of the rod, *viz.* that from which the electrometer hangs, be touched with some Conductor, the cork-balls will come immediately together, and they will remain so when the Conductor has been removed;

—remove

—remove now the excited glaſs tube, and the balls will immediately diverge with negative Electricity; which ſhows that the rod remains undercharged, *i. e.* electrified negatively.

The reaſon of this experiment is, that the repelling power of the excited tube, driving the fluid of one end of the rod to its other end, *i. e.* to that, with which the electrometer is connected, renders this end electrified poſitively; but in fact the tube communicates no Electricity to the rod, it only diſturbs the equable diffuſion of its fluid: in conſequence of this, the electrometer, hanging to the overcharged end of the rod, muſt neceſſarily appear to be electrified poſitively; but when the tube is removed, then the electrometer appears again unelectrified: for the fluid, which had by the action of the tube been driven to one end of the rod, now retires to its former ſituation, and leaves the rod with the electrometer, unelectrified.

In the ſecond caſe, when the balls of the electrometer diverge with poſitive Electricity, if that end of the rod be touched with

ſome conductor, all its ſuperfluous fluid, which is no other than that belonging to the oppoſite end of the rod, will be communicated to that body, with which the rod is touched, and therefore the electrometer remains unelectrified: but now in fact the rod has loſt ſome of its natural quantity of fluid; for if the end of it, that is fartheſt from the excited tube, remains in its natural ſtate, the other end is undercharged; conſequently, when the tube is removed, the ſmall quantity of fluid that remains in the rod will diffuſe itſelf uniformly through it; but this quantity of fluid is leſs than that naturally inherent in the rod; the rod will therefore remain undercharged, and hence the balls of the electrometer diverge with negative Electricity.

This explanation is the ſame as that mentioned in the preceding experiment, *viz.* in the method of electrifying an electrometer negatively, with a body poſſeſſed of poſitive electricity, &c.; but as this experiment is the baſis, or key, of ſeveral others, I ſhall inſiſt on it a little longer; and, to render its explanation more intelligible and

clear,

clear, I ſhall make uſe of the following diagram:

A ——————— B.

Let the above-mentioned inſulated rod be repreſented by the line A B. When this rod is in its natural ſtate (in reſpect to Electricity) then the electric fluid belonging to it, is equally diffuſed throughout the rod, But when the excited tube is brought within three or four inches diſtance of one of the ends, for inſtance B, then the fluid, belonging to that end, will be driven to the end A; which end therefore becomes overcharged, and the end B undercharged; yet the rod has no more electric fluid now, than it had before; and when the tube is removed to ſome diſtance from the rod, the ſuperfluous fluid, repelled to the end A, returns to its former place, *i. e.* to the end B, and the equilibrium in the rod is reſtored. But if, when the fluid in the rod is repelled to the end A, this end be touched, the fluid repelled thither will immediately be conducted away by the body that touched it, and will leave the end A

of the rod in a natural ſtate; but at the ſame time, the end B is undercharged; therefore, when the tube is removed, part of the natural fluid belonging to the end A, will go to the end B; and thus the whole rod will remain undercharged, *i. e.* negatively electrified.

If the above experiment be made with an electric negatively electrified (for inſtance, a rod of ſealing-wax inſtead of the excited glaſs tube) then the apparent Electricities in the rod will be juſt the reverſe of what they were before; for in this caſe, that end of the rod to which the electric has been preſented, will be overcharged, and the oppoſite end, undercharged; which oppoſite end, if touched in this ſtate with ſome conducting ſubſtance, will acquire ſome electric fluid from that ſubſtance; and when, after that ſubſtance has been removed, the excited electric is alſo removed, the rod will remain overcharged.

In making this experiment, care muſt be taken that the end of the rod be very blunt, and that the electric be not very

powerfully

powerfully excited; otherwise a spark may pass from this to the rod, which renders the experiment precarious.

EXPERIMENT VIII.

The two insulated metallic Rods.

Take two rods of metal, each about a foot long, furnished with knobs at both ends, and, either by silk lines, or by insulating stools, insulate them, so that they may stand horizontally in one direction, and about $\frac{1}{4}$ of an inch distance from one another. To the middle of each of these rods hang an electrometer, like that represented fig. 3. This done, take an excited glass tube, and bring it to about three inches distance from the knob of one of the rods; on doing which, the electrometers of both rods will appear electrified: keep the tube in that situation for about two seconds, then remove it. The rods now will remain electrified, as appears by the electrometers; the first, *viz.* that to which the excited tube had been presented, remaining negative, and the other positive.

The reaſon of this phenomenon is, that when the tube was near the end of one of the rods, the action of its fluid repelling the fluid of that rod, cauſed it to paſs in a ſpark to the other contiguous rod; on which account, when the tube was removed, the firſt rod, having loſt ſome of its natural fluid, remained undercharged; and the other rod, acquiring the fluid loſt by the former, became overcharged.

In this experiment, if, inſtead of the glaſs tube, an electric, negatively excited, be brought near the end of one rod, then that rod will be electrified poſitively, and the other negatively; for the action of this electric, producing juſt the contrary effect of the glaſs tube, inſtead of repelling the fluid of the firſt rod into the ſecond, attracts that of the ſecond into the firſt.

In this experiment the electric does not communicate any electricity of its own, but only diſturbs the equilibrium between the fluid of the rods.

CHAP.

CHAP. VI.

Experiments on electric Light.

THE following experiments require to be made in the dark; for although the electric light, in ſeveral circumſtances, may be ſeen in the day-light, yet its appearance in this manner is very confuſed; and, that the Electrician might form a better idea of its different appearances, it is abſolutely neceſſary to perform ſuch experiments in a darkened room.

EXPERIMENT I.

The Star and Pencil of electric Light.

When the electrical machine is in good order, and the prime Conductor is ſituated with the collector ſufficiently near the glaſs cylinder (which ſituation I ſhall call hereafter its proper place) turn the winch, and you will ſee a lucid ſtar at each of the points of the collector. This ſtar is the

conſtant

conſtant appearance of the electric fluid that is entering a point. At the ſame time, you will ſee a ſtrong light proceeding from the rubber, and ſpreading itſelf over the ſurface of the cylinder; and, if the excitation of the cylinder is very powerful, denſe ſtreams of fire will proceed from the rubber, and, darting round almoſt half the circumference of the cylinder, will reach the points of the collector *.

If the chain of the rubber be taken off, and a pointed body (as for inſtance, the point of a needle or pin) be preſented to the back of the rubber, at the diſtance of about two inches, a lucid pencil of rays will appear to proceed from the point preſented, and diverge towards the rubber.

* If the prime Conductor be removed, the denſe ſtreams of fire will go quite round the cylinder; reaching from one ſide of the rubber to the other.—By obſerving on which ſide of the cylinder thoſe ſtreams are moſt copious, it may be eaſily determined which ſide of the rubber preſſes more or leſs upon the cylinder, or is better covered with amalgam, or, in ſhort, which ſide is the moſt or leaſt fit for the excitation of the glaſs.

This

This pencil is the conſtant appearance of the electric fluid iſſuing from a point; and in fact, it now comes out of the point, in order to ſupply the rubber, which is conſtantly exhauſted by the cylinder in motion.

If another pointed body be preſented to the prime Conductor, it will appear illuminated with a ſtar; but if a pointed wire, or other pointed conducting body, be connected with the prime Conductor, it will throw out a pencil of rays; for the prime Conductor being overcharged, the fluid departing from it muſt, agreeably to the law, form a pencil on that point from which it flies off, and a ſtar on that point which it enters *.

F. BEC-

* It may be aſked, why the electric fluid entering a point, cauſeth the appearance of a ſtar; and when going out of the point, cauſeth the appearance of a bruſh of rays? In anſwer to this queſtion, F. BECCARIA ſuppoſes, that the ſtar is occaſioned by the difficulty with which the electric fluid is extricated from the air, which is an electric. Suppoſe, for inſtance, that a pointed wire is preſented to a body poſitively electrified, the electric fluid is firſt from that body communicated

F. BECCARIA remarks, that if two equally sharp points are approached to a prime Conductor, they will appear luminous at only half the distance at which one of them would have done.

From this experiment may be learned the method of distinguishing the quality of the Electricity of an electrified body, by the appearance of the electric light; for if a needle, or any other pointed body, be presented in the dark, with the point towards a body strongly electrified, it will appear illuminated with a star, when that body is electrified positively, and with a pencil or brush, when it is electrified negatively.

Here it is proper to remark, that when two points (one of which is connected with

cated to the air between it and the wire, and then the wire must extricate it from that air. The brush, he supposes to be occasioned by the force with which the electric fluid, going out of a point, runs through the contiguous air to that which is more remote from it; *i. e.* by dividing the contiguous air, and not by affixing itself to it.

the

the prime Conductor, or the rubber) are opposed to one another, the appearance of light in both is pretty much the same. Mr. WILCKE remarks, that when a point not electrified, is opposed to another point electrified positively, the cones of light, which otherwise would appear upon them, disappear; but that if a positive cone be opposed to a negative cone, they both preserve their own characteristic properties *.

EXPERIMENT II.

Drawing Sparks.

Let the prime Conductor be situated in its proper place, and electrify it by working the machine; then bring a metallic rod with a round knob at each end, or the knuckle of a finger, within a proper distance of the prime Conductor, and a spark will be seen between that and the knuckle, or knobbed wire. The longer and stronger

* WILCKE, p. 140.—See BECCARIA's Art. Elect. § 941, and following.

ſpark is drawn from that end of the prime Conductor which is fartheſt from the cylinder, or rather from the end of the knobbed rod I B, fixed at its end B, fig. 2 *.

This ſpark (which has the ſame appearance, whether drawn from a prime Conductor poſitively, or negatively electrified) appears like a long line † of fire, reaching from the Conductor to the oppoſed body; and often (particularly when the ſpark is long, and different conducting ſubſtances are near the line of its direction) it will have the appearance of being bent to ſharp angles in different places, exactly reſembling a flaſh of lightning. Notwithſtanding, however, this extended appearance, which is imputed to the quick paſſage of the luminous matter, the electric

* The reaſon of this is, becauſe that end of the prime Conductor is leſs influenced by the atmoſphere of the excited cylinder.

† It often darts bruſhes of light ſideways, in every direction.

fluid

fluid paſſing from one body to another in a ſpark, is reaſonably thought to proceed in a ſeparate, and nearly globular body.

The direction of the ſpark often deceives the moſt experienced Electrician, it ſeeming ſometimes to proceed from one place, and at other times, under the ſame circumſtances, to proceed from the oppoſite. When the prime Conductor is electrified poſitively, the ſpark muſt certainly proceed from it, and go to the body preſented; and when the prime Conductor is electrified negatively, the ſpark muſt proceed from the body preſented, and go to the Conductor. This, however, we learn by reaſoning from other experiments; for the real direction of the ſpark in the above experiment, is much more rapid in its motion than to admit its form, much leſs its direction, to be perceived by our eyes. With Mr. NAIRNE's machine, which is very powerful, it is obſervable, firſt, that the ſparks from the negative Conductor are more pungent than thoſe from the poſitive; and ſecondly (which may be the cauſe of the preceding effect), that when a blunt body is

presented to the negative Conductor, the spark appears branched towards the Conductor, and concentrated in one stock towards the body; but with the positive Conductor the appearance of the spark is just the reverse.

A longer spark may be drawn from a larger than from a smaller Conductor, except when the Conductor exceeds a certain size. The Conductor, which, when put before an ordinary electrical machine, will give sparks about equal in length to the diameter of the glass cylinder of the machine, is the largest that can be used to advantage; for a longer spark cannot be obtained, except in some particular cases, *viz.* when some particles of dust, or other extraneous matter, happen to be interposed between the Conductor and the brass ball, or other substance, that is opposed to it, &c. as will appear from the following reasoning:—The circumference of the glass cylinder is nearly equal to three times its diameter. The rubber, with its piece of silk, &c. may occupy about one third part of the said circumference, and consequently

consequently the collector of the Conductor, when put in the middle of the remaining surface, at most cannot be farther from the rubber than the length of one diameter of the cylinder, *viz.* one third part of the circumference; therefore it is plain, that if the conductor could give a spark longer than the diameter of the cylinder, the spark would be darted to the rubber, rather than to any other body placed farther off from the Conductor.— When the rubber of the machine is made to communicate with the earth, by means of imperfect Conductors, as a piece of wood, &c. then the Conductor will give a spark generally longer than when perfect Conductors are employed for the said communication. In this case it may happen, that a spark some small matter longer than the diameter of the cylinder, might be obtained.

EXPERIMENT III.

To fire inflammable Spirits.

The power of the electric ſpark to ſet fire to inflammable ſpirits, may be exhibited by ſeveral different methods; but more eaſily thus:—Hang to the prime Conductor a ſhort rod, having a ſmall knob at its end, then pour ſome ſpirit of wine, a little warmed, into a metal ſpoon *; hold the ſpoon by the handle, and place it in ſuch a manner, that the ſmall knob on the rod may be about one inch above the ſurface of the ſpirit. In this ſituation, if, by turning the winch, a ſpark be made to come from the knob, it will ſet the ſpirit on fire.

* The readieſt way to warm the ſpirits for this experiment, is to ſet it on fire with a candle when it is in the ſpoon, and, after it has burned for about two or three ſeconds, to blow it out with your breath. In this ſtate it will be found very ready to take fire, even by a ſmall ſpark.

This experiment happens in the very ſame manner, whether the Conductor is electrified poſitively or negatively, *i. e.* whether the ſpark be made to come from the Conductor or from the ſpoon; it being only in conſequence of the rapid motion of the ſpark that the ſpirits are kindled.

It will be perhaps ſcarce neceſſary to remark, that the more inflammable the ſpirits are, the more proper they will be for this experiment, as a ſmaller ſpark will be ſufficient to inflame them; therefore rectified ſpirit of wine is better than common proof ſpirit, and æther is better than either.

This experiment may be varied different ways, and may be rendered very agreeable to a company of ſpectators. A perſon, for inſtance, ſtanding upon an electric ſtool, and communicating with the prime Conductor, may hold the ſpoon with the ſpirits in his hand, and another perſon, ſtanding upon the floor, may ſet the ſpirits on

fire, by bringing his finger within a ſmall diſtance of it. Inſtead of his finger, he may fire the ſpirits with a piece of ice; when the experiment will ſeem much more ſurprizing. If the ſpoon is held by the perſon ſtanding upon the floor, and the inſulated perſon brings ſome conducting ſubſtance over the ſurface of the ſpirit, the experiment ſucceeds as well.

Mr. WINCKLER ſays, "that oil, pitch, "and ſealing-wax, might be lighted by "electric ſparks, provided thoſe ſubſtances "were firſt heated to a degree next to "kindling. To theſe it muſt be added, "that Mr. GRALATH fired the ſmoke of "a candle juſt blown out, and lighted it "again; and that Mr. BOZE fired gun-"powder, melting it in a ſpoon, and firſt "the vapour that roſe from it *.

* PRIESTLEY's Hiſt. of Elect. period VII.

EXPE-

EXPERIMENT IV.

The artificial Bolonian Stone illuminated by the electric Light.

The moſt curious experiment to ſhew the penetrability of the electric light, is made with the real, or with the artificial Bolonian ſtone, which is procured more eaſily, and was invented by the late Mr. J. CANTON. This phoſphorus is a calcareous ſubſtance, generally uſed in the form of a powder, which has the property of appearing lucid, when brought into the dark after having been expoſed to the light *.

Put

* The method of making this phoſphorus is as follows: "Calcine ſome common oyſter-ſhells" (if they be old, and half calcined by time, ſuch as are commonly found upon the ſea-ſhore, they are, as Mr. W. CANTON obſerves, ſo much the better) "by keeping "them in a good coal-fire for half an hour; let the "pureſt part of the calx be pulverized and ſifted; "mix with three parts of this powder one part of the "flowers of ſulphur; let this mixture be rammed into "a crucible of about an inch and a half in depth, till it "be

Put ſome of this powder in a clear glaſs phial, and ſtop it with a glaſs ſtopper, or a cork and ſealing-wax. If this phial be kept in a darkened room (which for this experiment muſt be very dark) it will give no light; but let two or three ſtrong ſparks be drawn from the prime Conductor, when the phial is kept at about two inches diſtance from the ſparks, ſo that it may be expoſed to that light, and this phial will receive the light, and afterwards will appear illuminated for a conſiderable time.

" be almoſt full; and let it be placed in the middle of " the fire, where it muſt be kept red-hot for one hour " at leaſt, and then ſet it by to cool: when cold, turn " it out of the crucible, and cutting or breaking it to " pieces, ſcrape off, upon trial, the brighteſt parts: " which, if good phoſphorus, will be a white powder, " and may be preſerved by keeping it in a dry phial " with a ground ſtopple."

If this phoſphorus, whether in the phial or not, be kept in the dark, it will give no light, but if expoſed to the light, either of the day, or of any other luminous body, and afterwards brought into a dark place, it will then appear lucid for a conſiderable time. For farther properties of this phoſphorus, ſee the Phil. Tranſ. Vol. LVIII.

This

This powder may be ſtuck upon a board by means of the white of an egg, ſo as to repreſent figures of planets, letters, or any thing elſe, at the pleaſure of the operator, and theſe figures may be illuminated in the dark, in the ſame manner as the above-deſcribed phial.

A beautiful method to expreſs geometrical figures with the above phoſphorus, is to bend ſmall glaſs tubes, of about the tenth part of an inch diameter, in the ſhape of the figure deſired, and then to fill them with the phoſphorus powder. Theſe may be illuminated in the manner deſcribed, and they are not ſo ſubject to be ſpoiled, as the figures repreſented upon the board frequently are.

The beſt method of illuminating this phoſphorus, and was that Mr. W. CANTON generally uſed, is to diſcharge a ſmall electric jar near it.

Paper, after being made dry and rather hot, marble, oyſter-ſhells, and moſt calcareous ſubſtances, eſpecially when burned to lime,

lime, have the property of being illuminated by the light given by the diſcharge of a jar, though not ſo much as the above-mentioned phoſphorus.

Experiment V.

The luminous Conductor.

Fig. 6. Plate I. repreſents a prime Conductor invented by Mr. Henly, which ſhews clearly the direction of the electric fluid paſſing through it, from whence it is called *the luminous Conductor* *. The middle part EF of this Conductor, is a glaſs tube about eighteen inches long, and three or four inches in diameter. To both ends of this tube the hollow braſs pieces FD, BE, are cemented air-tight, one of which has a point C, by which it receives the electric fluid, when ſet near the excited cylinder of the electrical machine, and the

* An inſtrument much like this Conductor was ſome years ago contrived by Dr. Watson, with which he made ſeveral original experiments upon the electric light.

other

other has a knobbed wire G, from which a ſtrong ſpark may be drawn; and from each of the pieces FD, BE, a knobbed wire proceeds, within the cavity of the glaſs tube. The braſs piece FD, or BE, is compoſed of two parts, *i. e.* a cap F cemented to the glaſs tube, and having a hole with a valve, by which the cavity of the glaſs tube may be exhauſted of air; and the ball D, which is ſcrewed upon the cap F. The ſupporters of this inſtrument are two glaſs pillars faſtened in the bottom board H, like the prime Conductor repreſented fig. 2. When the glaſs tube of this Conductor is exhauſted of air by means of an air-pump, and the braſs ball is ſcrewed on, as repreſented in the figure, then it is fit for uſe, and may ſerve for a prime Conductor to an electrical machine.

If the point C of this Conductor is ſet near the excited cylinder of the machine, it will appear illuminated with a ſtar; at the ſame time the glaſs tube will appear all illuminated with a weak light; but from the knobbed wire, that proceeds within the glaſs from the piece FD, a lucid pencil will

will iſſue out, and the oppoſite knob will appear illuminated with a ſtar or round body of light, which, as well as the pencil of rays, is very clear, and diſcernible among the other light, that occupies the greateſt part of the cavity of the tube.

If the point C, inſtead of being preſented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reverſed; the knob which communicates with the piece FD appearing illuminated with a ſtar, and the oppoſite with a pencil of rays; becauſe in this caſe the direction of the electric fluid is juſt the contrary of what it was before; it then going from D to B, and now coming from B and going to D.

If the wires within the tube EF, inſtead of being furniſhed with knobs, be pointed, the appearance of light is the ſame, but it ſeems not ſo ſtrong in this, as in the other caſe.

EXPERIMENT VI.

The conducting Glaſs Tube.

Take a glaſs tube of about two inches diameter, and about two feet long; fix to one of its ends a braſs cap, and to the other a ſtop-cock, or a valve; then by means of an air-pump exhauſt it of air. If this tube be held by one end, and its other end be brought near the electrified prime Conductor, it will appear to be full of light, whenever a ſpark is taken by it from the prime Conductor; and much more ſo, if an electric jar be diſcharged through it.

This experiment may alſo be made with the receiver of an air-pump.—Take, for inſtance, a tall receiver, clean and dry, and through a hole at its top inſert a wire, which muſt be cemented air-tight. The end of the wire, that is within the tube, muſt be pointed, but not very ſharp; and the other end muſt be furniſhed with a knob. Put this receiver upon the plate of the

the air-pump, and exhauſt it. If now the knob of the wire at the top of the receiver be touched with the prime Conductor *, every ſpark will paſs through the receiver in a denſe and large body of light, from the wire to the plate of the air-pump.

It muſt be obſerved, that when the air is very much rarefied, the electric light in it is leſs denſe, though more diffuſed, and contrarywiſe.

EXPERIMENT VII.

The Aurora Borealis.

Take a phial nearly of the ſhape and ſize of a Florence flaſk; fix a ſtop-cock or a valve to its neck, and exhauſt it of air as much as it is poſſible with a good air-pump. If this glaſs be rubbed in the common manner uſed to excite electrics, it will

* When any thing is to be touched with the prime Conductor, that is not very portable, as the air-pump above-mentioned, the communication between the former and the latter may be made by means of a rod furniſhed with an electric handle, or the like.

appear luminous within, being full of a flashing light, which plainly resembles the aurora borealis, or northern light. This phial may also be made luminous by holding it by either end, and bringing the other end to the prime Conductor; in this case all the cavity of the glass will instantly appear full of flashing light, which remains in it for a considerable time after it has been removed from the prime Conductor.

Instead of the above-described glass vessel, a glass tube, exhausted of air and hermetically sealed, may be used, and perhaps with greater advantage. The most remarkable circumstance of this experiment is, that if the phial or tube, after it has been removed from the prime Conductor (and even several hours after its flashing light hath ceased to appear) be grasped with the hand, strong flashes of light will immediately appear within the glass, which often reach from one of its ends to the other.

The causes on which this experiment depends, are two; first, the conducting nature of the vacuum; and, second, the charging

ing of the glaſs: for when one ſide of the glaſs phial is touched with the prime Conductor, the electric fluid, communicated to the outſide ſurface of one ſide of the phial, cauſeth the natural fluid belonging to the inſide ſurface to depart from its place, and go to the oppoſite ſide of the phial; and this fluid, paſſing through the vacuum, cauſes the light within the phial, which light is more or leſs ſubdivided, according as the vacuum is leſs or more perfect. Now, that part of the phial, which has touched the prime Conductor, is actually charged; for its outſide ſurface has acquired an additional quantity of electric fluid, and the inſide ſurface has loſt part of its own; but as the outſide of the phial has no coating, therefore, when it is removed from the prime Conductor, and is not graſped with the hand, or other Conductor, the charged part of the glaſs can be diſcharged only gradually; that is, whilſt its outſide ſurface is communicating its ſuperfluous fluid to the contiguous air, the inſide ſurface acquires the electric fluid from the other end of the phial, and this fluid paſſing through the vacuum, cauſes that flaſhing, which

which is obſerved for ſo conſiderable a time. If the phial be graſped with the hand, its diſcharge is accelerated, hence the flaſhes within the phial appear more denſe and copious; yet it cannot be diſcharged all at once by this operation, becauſe the hand cannot touch every part of the glaſs at once.

EXPERIMENT VIII.

The viſible electric Atmoſphere.

GI fig. 2. Plate II. repreſents the receiver with the plate of an air-pump. In the middle of the plate IF, a ſhort rod is fixed, having at its top a metal ball B nicely poliſhed, whoſe diameter is nearly two inches. From the top of the receiver another rod AD with a like ball A proceeds, and is cemented air-tight in the neck C; the diſtance of the balls from one another being about four inches, or rather more. If, when the receiver is exhauſted of air, the ball A be electrified poſitively, by touching the top D of the rod AD with the prime Conductor or an excited glaſs

tube, a lucid atmoſphere appears about it, which, although it conſiſts of a feeble light, is yet very conſpicuous, and very well defined; at the ſame time the ball B has not the leaſt light. The atmoſphere does not exiſt all round the ball A, but reaches from about the middle of it, to a ſmall diſtance beyond that ſide of its ſurface, which is towards the oppoſite ball B. If the rod with the ball A be electrified negatively, then a lucid atmoſphere, like the above-deſcribed, will appear upon the ball B, reaching from its middle to a ſmall diſtance beyond that ſide of it, that is towards the ball A; at the ſame time the negatively electrified ball A remains without any light.

The Operator, in this experiment, muſt be careful not to electrify the ball A too much, for then the electric fluid will paſs in a ſpark from one ball to the other, and the experiment will not have the deſired effect. A little practice, however, will render the operation very eaſy and familiar.

By this elegant experiment, which is of the celebrated F. BECCARIA, we have an ocular

ocular demonſtration of the theory of a ſingle electric fluid; we ſee that Electricity conſiſts of one uniform homogeneous fluid, and not of two, *viz.* the vitreous and reſinous, as ſome have ſuppoſed; for if the poſitive and negative Electricity were two diſtinct fluids, attractive of one another, there ſhould, in the above experiment, always appear two atmoſpheres, *i. e.* one about the ball A, and another about the ball B; for when the ball A is overcharged with either fluid, it ſhould ſhew that ſuperfluous fluid on its ſurface, and this fluid ſhould attract towards the ball A, an atmoſphere of the contrary fluid from the ball B. But this, as we obſerved before, is not the caſe; for the appearance of the lucid atmoſphere is always on one ball, namely, that which is overcharged with the electric fluid; thus, when the ball A is electrified poſitively, the ſuperfluous fluid is viſible on that part of it which is neareſt to the ball B, becauſe B, being in a contrary ſtate of Electricity, endeavours to attract it; but, when the ball A is electrified negatively, it will attract the fluid proper to the ball B, which fluid on that account appears upon

the ſurface of B, juſt in the act of leaping to the ball A.

In order to remove an error, that has been adopted by ſeveral writers on Electricity, it will not be amiſs in this chapter to mention, that the electric light has all the priſmatic colours, as well as the light of the ſun. This may be eaſily obſerved by viewing an electric ſpark through a glaſs priſm *.

* See Dr. PRIESTLEY's Hiſtory of Electricity, part VIII. ſec. XIII. n. XII.

CHAP.

CHAP. VII.

Experiments with the Leyden Phial.

EXPERIMENT I.

Of charging, and discharging a Phial in general.

TAKE a coated jar, as D E, fig. 11, Plate I, and place it upon the table near the prime Conductor, so that the knob of its wire, and that only, may be in contact with it: fix the quadrant electrometer E, fig. 2, upon the prime Conductor, and then turn the winch of the machine. You will observe, that as the jar is charging, the index of the electrometer will rise gradually as far as 90°, or thereabouts, and then rest: when this happens, you may conclude, that the jar has received its full charge. If now you take a discharging rod, and, holding it by the glass handle, apply first one of its knobs to the outside coating of the jar, and then bring the other knob near the knob of the wire of the jar,

or near the prime Conductor, that communicates with it, you will hear a report, and ſee very vivid ſparks between the diſcharging rod and the conducting ſubſtances, communicating with the ſides of the jar. This operation diſcharges the jar. If, inſtead of uſing the diſcharging rod, you touch the outſide of the jar with one hand, and bring the other hand near the wire of the jar, the ſame ſpark and report will follow, but now you will feel a ſhock, which affects your wriſts, elbows, and, if ſtrong, your breaſt alſo *. If a number of perſons join hands, and the firſt of them touches the outſide of the jar, and the laſt touches the wire communicating with the inſide, they will all feel the ſhock, and preciſely at the ſame perceivable time. This ſhock bearing no reſemblance to any ſenſation otherwiſe felt, cannot conſequently be deſcribed; and in order that a perſon may form a juſt idea of it, he muſt abſolutely feel it.

If many perſons lay hold of a metal plate that communicates with the outſide of a

* A ſhock may be given to any ſingle part of the body, if that part only be brought into the circuit.

charged

charged jar, and all together do alſo hold a metal rod with which the diſcharge is made, they will all feel the ſhock; which ſhews that the diſcharge has been made through ſeveral circuits at once.

The reaſon of the charging of the phial or jar in this experiment is, that when a ſuperfluous quantity of electric fluid is forced upon the inſide ſurface of the glaſs, it cauſeth an equal quantity of fluid, naturally inherent in the glaſs, to depart from the oppoſite ſurface, in conſequence of the repulſion natural to the particles of the electric fluid, which repulſion is exerted even through the glaſs; one ſide therefore of the glaſs remains overcharged, and the other undercharged; as ſoon, therefore, as the communication between the two ſides of the jar is compleated, the ſuperfluous fluid on one ſide of the glaſs flies violently to the other ſide, and the rapidity of its motion occaſions the ſpark, the report, &c.

If the coated jar be held by the wire communicating with its inſide, and the outſide coating be preſented to the prime

Conductor, it will be charged as readily as in the other method, but with this difference, that in this caſe the outſide will be poſitive and the inſide negative.

We have ſuppoſed above, that the prime Conductor was electrified poſitively; but if the experiment be repeated when the Conductor, by being connected with the rubber of the machine, is electrified negatively, the jar will in the ſame manner be charged; except that in this caſe the ſide that touches the prime Conductor will be electrified negatively, and the oppoſite ſide poſitively.

EXPERIMENT II.

To ſhew that an inſulated Jar cannot be charged.

Set a coated jar upon an electric ſtool; connect its wire, or its outſide coating with the prime Conductor, and turn the winch of the machine. You will then obſerve, that the index of the quadrant electrometer, placed upon the prime Conductor, ſoon riſes

rises to 90°, seemingly shewing that the jar is charged. Then remove the electric stool with the jar from the prime Conductor, and either with a discharging rod, or with your hands, endeavour to discharge the jar, and you will find, that it is not charged; for no remarkable spark, no shock, nor any other phenomenon of charged glass will appear.

The reason why in this experiment the inside of the jar could acquire no additional electric fluid, and therefore the jar could acquire no charge, is because the outside could not at the same time part with its own fluid, its communication with the earth being cut off by the electric stool. But repeat this experiment with only this variation, that, by means of a chain or otherwise, the outside of the jar be made to communicate with the table, and you will then find, that the jar will be charged; for in this case the fluid, naturally inherent in the outer surface of the jar, can readily be repelled through the chain, &c. into the table.

Strictly

Strictly ſpeaking, the jar in this experiment will acquire a very ſlight charge, becauſe ſome of the electric fluid belonging to its outſide will be imparted to the air, &c.

If a jar be inſulated, and one ſide of it, inſtead of being connected with the earth, be connected with the inſulated rubber, whilſt the other ſide communicates with the prime Conductor, the jar will be alſo charged, and perhaps in a more expeditious manner; for whilſt the rubber exhauſts one ſide, the other ſide is ſupplied by the prime Conductor. In this manner it is ſhown, that the jar is charged with its own fluid, *i. e.* the natural electric fluid of one of its ſides is, by the action of the machine, thrown on the other ſide.

EXPERIMENT III.

The preceding Experiment diverſified.

To make the above experiment in a clearer, and more ſatisfactory manner, place the jar upon the ſtool as before, and

 with

with its wire not in contact, but at about half an inch distance from the prime Conductor; hold the knob of another wire at such a distance from the outside coating of the jar, as the knob of the jar is from the prime Conductor, then let the winch of the machine be turned, and you will observe, that whenever a spark comes from the prime Conductor to the wire of the jar, another spark passes from the outside coating of the jar to the knob of the wire presented towards it; which shews, that as a quantity of electric fluid is entering the inside of the jar, an equal quantity of it is leaving the outside. In this manner the jar becomes charged.

If instead of the knobbed wire, a pointed one be presented to the outside of the jar, it will appear illuminated with a star; and if instead of presenting any wire to the jar, a pointed wire be connected with its coating, it will appear illuminated with a brush of rays (*i. e.* by throwing the electric fluid into the air), which will last as long as the jar is charging.

If

If the knob of another jar be preſented to the outſide coating of the inſulated jar in the above experiment, it will alſo be charged; for the fluid, going out of the outſide coating of the firſt jar, *i. e.* that ſtanding upon the ſtool, will go in the inſide of the other jar, and cauſe the fluid, inherent to the outſide of that jar, to depart from its place *.

Experiment IV.

To ſhew that the Charge of a Jar, or Glaſs in general, does not reſide in the Coating.

Take a naked phial, and for a coating on the outſide ſtick a piece of tin-foil, with a little tallow or bees-wax, ſo that it can juſt adhere to the glaſs; and for an inſide

* One will eaſily imagine from this experiment, how ſeveral phials may be connected together, ſo that they may be charged all at once, with nearly the ſame trouble as one is charged. It muſt, however, be obſerved, that when ſeveral jars are ſo connected, that the inſide of one communicates with the outſide of another, &c. they cannot be charged ſo high, nor ſo eaſily, as otherwiſe; the difficulty increaſing nearly in proportion to the number of jars.

coating

coating uſe ſmall leaden ſhot, or quick-ſilver; laſtly, inſert through its neck a knobbed wire communicating with the ſhot or quickſilver.—This done, hold the phial thus coated by its outſide coating, and charge it, by preſenting its knobbed wire to the prime Conductor. When it is charged, turn it upſide down, and let its wire and quickſilver, or ſhot, fall in a glaſs receiver; then remove its outſide coating alſo. In this operation the phial does not loſe its charge, and if you examine the quickſilver or ſhot, you will find that it contains no more Electricity than any other like conducting inſulated body, which has been in contact with the prime Conductor, would contain. Replace the outſide coating again upon the phial, pour the ſhot or quick-ſilver again into it, or any other conducting ſubſtance, then touch with one hand the outſide coating, and with the other, by introducing a finger or a wire, touch the inſide non-electric, and you will feel a ſhock; which will convince you, that the glaſs has loſt very little of its charge by the operation above-mentioned.

The ſame experiment may be more conveniently made by laying a pane of glaſs upon a metal plate, and covering an equal part of the upper ſurface with tin-foil, having a ſilk thread faſtened to one of its ſides, by which it may be eaſily taken off, when the glaſs is charged, and as eaſily replaced, when required.

EXPERIMENT V.

To prove that the electric Fluid does not expel the Air contained in a Phial.

Through a hole made in the cork that ſtops a coated phial, introduce a ſmall glaſs tube open at both ends, and of about one thirtieth part of an inch in diameter; bend that part of the tube, that is out of the phial, in an horizontal ſituation, and with bees-wax faſten the cork ſo, that no air can get in or out of the phial, except it paſſes through the glaſs tube; laſtly, put a ſmall drop of red wine, or ink, in the horizontal part of the tube, ſo that it may be eaſily moved through it, by the leaſt rarefaction or condenſation of the air within the phial.

If

If this phial thus furniſhed be charged, by connecting the prime Conductor with its wire, the drop of liquor in the glaſs tube will not be ſtirred from its ſituation; which ſhews that the electric fluid, immitted into the phial, does not exclude any of the air that the phial contains. If the phial be diſcharged, the drop of liquor in the tube will be often puſhed a little out of its place, and afterwards return to its former ſituation; which ſhews, that on making the diſcharge, the air within the phial was a little diſplaced, or rarefied. This, however, is to be imputed to ſome ſpark, that generally happens within the cavity of the phial, on account that the wire is not in perfect contact with the inſide coating *.

* Having repeated this experiment with a ſmall phial, whoſe charging-piece (as we may call it) was a production of the inſide coating, (which was of one piece of tin-foil ſtuck to the glaſs with bees-wax, in conſequence of which no ſpark could happen within the phial) I found that the drop of liquor in the glaſs tube was not ſtirred, either in charging or diſcharging the phial.

EXPE-

EXPERIMENT VI.

The Courſe of the electric Fluid in the Diſcharge rendered viſible by the Star and Pencil.

When a jar is charged, take a diſcharging rod having its ends pointed, *i. e.* the diſcharging rod repreſented in fig. 10. Plate I. without its knobs, and keep it as repreſented, fig. 11. that is, in ſuch a ſituation, that one of its points C may be at about an inch diſtance from the knob A, and the other point B at an equal diſtance from the outſide coating of the jar; by theſe means the jar will be diſcharged ſilently; and if its inſide be electrified poſitively, you will ſee, that the point C of the diſcharging rod is illuminated with a ſtar, and the point B with a pencil; becauſe, in this caſe, the electric fluid, going from the inſide to the outſide of the jar, enters the point C, and iſſues from the point B. But when the jar is electrified negatively on the inſide, and conſequently poſi-

 tive

tive on the outſide, then the pencil of rays will appear upon the point C, and the ſtar upon the point B; for in this caſe the electric fluid paſſes from the outſide to the inſide of the jar.

N. B. This experiment, as well as any other, in which the electric light is to be obſerved, requires to be made in the dark.

EXPERIMENT VII.

The Courſe of the electric Fluid in the Diſcharge ſhewn by the Flame of a Wax-taper.

Remove the circular piece of wood E from the univerſal diſcharger, repreſented fig. 5. Plate I. Fix the wires DB, DC, ſo that their knobs DD may be about two inches diſtant from one another; and upon the ſocket F fix a piece of wax-taper lighted, ſo that its flame may be juſt in the middle between the knobs DD. Having diſpoſed the apparatus in this manner, if you connect, by means of a chain or otherwiſe, the outſide of a charged jar with one

of the wires C, and bring the knob of the jar to the other wire C, you will obſerve, that on making the diſcharge, which muſt paſs between the knobs DD, the flame of the wax-taper is always driven in the direction of the electric fluid; that is, it will be blown upon the knob of that wire, which communicates with that ſide of the jar which is negatively electrified.

In this experiment, the jar muſt have an exceeding ſmall charge, juſt ſufficient to paſs through the interval in the circuit; which experience will preſently determine; otherwiſe the experiment will not ſucceed, or be perhaps rendered equivocal*.

* If it be aſked, Why this experiment does not ſucceed with a great exploſion as well as with a very ſmall one? the anſwer is, that when a jar highly charged, is brought near one of the wires of the univerſal diſcharger, it creates an atmoſphere about the knob of the ſaid wire, which atmoſphere diſturbs the flame of the wax-taper, before the actual diſcharge: beſides, the electric fluid in a great exploſion, by its elaſtic nature, paſſes through the flame of the wax-taper too ſwiftly to communicate to it any viſible motion; in the ſame manner as a bullet, diſcharged from a piſtol againſt an open door, makes a hole through the door without ſhutting it.

EXPE-

EXPERIMENT VIII.

The Courſe of the electric Fluid in the Diſcharge, rendered conſpicuous by the Motion communicated to a Pith Ball.

Bend a card, length-ways, over a round ruler, ſo as to form a channel, or ſemicircular groove*: lay this card upon the circular board E of the univerſal diſcharger, repreſented fig. 5. of Plate I. and in the middle of it put a pith-ball of about half an inch diameter; then at equal diſtances, about half or three quarters of an inch from the pith-ball, lay the two braſs knobs DD. The card being perfectly dry, and rather hot, if you connect, by means of a chain or otherwiſe, the outſide of a charged jar with one of the wires C, and bring the knob of

* Inſtead of the card, a piece of baked wood may be cut in that ſhape, and painted over with lamp-black and oil; which will anſwer better than the card, it being much more ſteady, and not ſo liable to attract moiſture.

the jar to the other wire C, you will observe, that on making the discharge, which must pass between the knobs D D, and over the card, &c. the pith-ball is always driven in the direction of the electric fluid; *i. e.* it is pushed towards that knob which communicates with the negative side of the jar.

It must be observed, that in this experiment the charge of the jar must be just sufficient to pass through the interval in the circuit; the card, or piece of baked wood, must be very dry and clean; and, in short, the disposition of the apparatus, and the performance of this curious experiment, require a degree of nicety that can only be obtained by practice. Without great precaution, it sometimes fails; but when the operator has once got it to succeed, and follows exactly the same method of operating, he may be sure that the event of the experiment will be constantly as above described.

EXPE-

EXPERIMENT IX.

The Leyden Vacuum.

Fig. 8 and 9. of Plate I. reprefent a fmall phial coated on the outfide about three inches up the fides with tin-foil; at the top of the neck of this phial, a brafs cap is cemented, having a hole with a valve, and from the cap a wire proceeds a few inches within the phial, terminating in a blunt point. When this phial is exhaufted of air, a brafs ball is fcrewed upon the brafs cap, fo as to defend the valve, and prevent any air from getting into the exhaufted glafs*. This phial exhibits clearly the direction of the electric fluid, both in charging and difcharging; for if it be held by its bottom, and its brafs knob be prefented to the prime Conductor pofitively electrified, you will fee that the

* The infide of this phial requires no coating, becaufe, as the electric fluid pervades vacuum, it can pafs freely from the wire to the furface of the exhaufted glafs, without the help of a non-electric coating.

electric fluid causeth the pencil of rays to proceed from the wire within the phial, as represented fig. 9. and when it is discharged, a star will appear in the place of the pencil, as represented in fig. 8. But if the phial be held by the brass cap, and its bottom be touched with the prime Conductor, then the point of the wire, on its inside will appear illuminated with a star when charging, and with a pencil when discharging. If it be presented to a prime Conductor electrified negatively, all these appearances, both in charging and discharging, will be reversed.

This experiment of the Leyden Vacuum, together with the two preceding ones, namely the seventh and eighth of this chapter, are inventions of the late Mr. HENLY.

EXPERIMENT X.

To pierce a Card, and other Subſtances, with the electric Exploſion.

Take a card, a quire of paper, or the cover of a book, and keep it cloſe to the outſide coating of a charged jar; put one knob of the diſcharging rod upon the card, quire of paper, &c. ſo that between the knob and coating of the jar, the thickneſs of that card, or quire of paper, only is interpoſed; laſtly, by bringing the other knob of the diſcharging rod near the knob of the jar, make the diſcharge; and the electric matter ruſhing through the circuit, from the poſitive to the negative ſurface of the jar, will pierce a hole (or perhaps ſeveral) quite through the card, or quire of paper *. This hole has a bur raiſed on

* The hole or holes, are larger or ſmaller, according as the card, &c. is more damp or more dry. It is remarkable, that if the noſtrils are preſented to it, they will be affected with a ſulphureous, or rather a phoſphoreal ſmell, juſt like that produced by an excited Electric.

each ſide, except the card, &c. be preſſcd hard between the diſcharging rod and the jar; which ſhews that the hole is not made in the direction of the paſſage of the fluid, but in every direction from the center of the reſiſting body.

If this experiment be made with two cards inſtead of one, which however muſt be kept very little diſtant from one another *, each of the cards, after the exploſion, will be found pierced with one or more holes, and each hole will have burs on both ſurfaces of each card.

If, inſtead of paper, a very thin plate of glaſs, roſin, ſealing-wax, or the like, be interpoſed between the knob of the diſcharging rod, and the outſide coating of the jar, on making the diſcharge, this will be broken in ſeveral pieces.

Small inſects may alſo be killed in this manner; they may be held between the

* This may be eaſily effected by bending one of the cards a little.

outſide

outſide coating of the jar, and the knob of the diſcharging rod, like the above-mentioned card; and a ſhock of a common phial ſent through them, will inſtantly deprive them of life, if they are pretty ſmall; but if larger, they will be affected in ſuch a manner, as to appear quite dead on firſt receiving the ſtroke, but will, after ſome time, recover: this, however, depends on the quantity of the charge ſent through them.

If a ſhock is ſent through a lump of white ſugar, ſtrong enough to break the ſugar, the ſhock will illuminate every piece of it, ſo as to afford a beautiful experiment in the dark.—The ſugar will give light for about a minute afterwards.

EXPERIMENT XI.

To ſhew the Effect of the Shock ſent over the Surface of a Card or other Subſtances.

Put the extremities of two wires upon the ſurface of a card, or other body of an electric nature, ſo that they may be in one

one direction, and about one inch diſtance from one another; then, by connecting one of the wires with the outſide of a charged jar, and the other wire with the knob of the jar, the ſhock will be made to paſs over the card or other body.

If the card be made very dry, the lucid track between the wires will be viſible upon the card for a conſiderable time after the exploſion. If a piece of common writing-paper be uſed inſtead of the card, it will be torn by the exploſion into very ſmall bits.

If, inſtead of the card, the exploſion is ſent over the ſurface of a piece of glaſs, this will be marked with an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. In this manner the piece of glaſs is very ſeldom broken by the exploſion. But Mr. HENLY has diſcovered a very remarkable method of increaſing the effect of the exploſion upon the glaſs; which is by preſſing with weights that part of the glaſs, which lies between the two

wires,

wires, (*i. e.* that part, over which the ſhock is to paſs). He puts firſt a thick piece of ivory upon the glaſs, and places upon that ivory a weight at pleaſure, from one quarter of an ounce to ſix pounds: The glaſs in this manner is generally broken by the explosion into innumerable fragments, and ſome of it is abſolutely reduced into an impalpable powder. If the glaſs is very thick, and reſiſts the force of the exploſion, ſo as not to be broken by it, it will be found marked with the moſt lively priſmatic colours, which are occaſioned by very thin laminæ of the glaſs, in part ſeparated from it by the ſhock. The weight laid upon the glaſs is always ſhook by the exploſion, and ſometimes it is thrown quite off from the ivory *. This experiment may be moſt conveniently made with the univerſal diſcharger. Fig. 5. of Plate I.

* If ſmall repreſentations of houſes, &c. be laid upon a board, placed on the piece of ivory; that, being ſhook by the exploſion, will give a very natural idea of an earthquake.

Experiment XII.

To shew the Direction of the electric Fluid in the Discharge, by causing the Shock to go over the Surface of a Card.

Dispose the apparatus in the manner described in the preceding experiment, but with this difference, that instead of laying the extremities of both wires upon the same side of the card, one of them be placed under the card; then send a shock through the said wires, as in the preceding experiment, and you will observe, that the electric fluid will run over that surface of the card, upon which lies the extremity of that wire, which is connected with the positive side of the jar; and in order to pass to the extremity of the other wire, it will break a hole through the card just over the extremity of that wire, which is connected with the negative side of the jar.

This excellent experiment, which shows the direction of the electric fluid in the discharge of a jar, is a discovery of Mr. Lullin, of Geneva.

N. B.

N. B. With very large jars, this experiment has been obſerved to pierce ſeveral holes, and in ſuch a manner as to render the reſult not ſatisfactory.

EXPERIMENT XIII.

To ſwell the Clay, and break ſmall Tubes with the electric Exploſion.

Roll up a piece of ſoft tobacco-pipe clay in a ſmall cylinder CD, fig. 4. Plate II. and inſert in it two wires A, B, ſo that their ends within the clay may be about a fifth part of an inch from one another. If a ſhock be ſent through this clay, by connecting one of the wires, A or B, with the outſide of a charged jar, and the other with the inſide, it will be inflated by the ſhock, *i. e.* by the ſpark, that happens between the two wires, and after the exploſion will appear as repreſented fig. 5. If the ſhock ſent through it is too ſtrong, and the clay not very moiſt, it will be broken by the exploſion, and its fragments ſcattered in every direction.

To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moiſt clay, then inſert in it two wires, as in the above rolled clay, and ſend a ſhock through it. This tube will not fail to burſt by the force of the exploſion, and its fragments will be ſcattered about to a great diſtance.

If, inſtead of clay, the above-mentioned tube of the tobacco-pipe, or a glaſs tube, (which will anſwer as well) be filled with any other ſubſtance, either electric or non-electric, inferior to metal, on making the diſcharge, it will be broken in pieces with nearly the ſame force.

This experiment is the invention of Mr. LANE, F. R. S.

EXPERIMENT XIV.

To ſhow the Courſe of the electric Fluid by the ſpontaneous Diſcharge.

Take a coated phial of a ſmall ſize, and if the naked part of it, *i. e.* from its outſide

ſide coating to the cork, is very dry, breathe upon it once or twice, ſo as to render it ſlightly damp: then holding the phial by its outſide coating, preſent its knob to the prime Conductor, while the machine is in action, and you will ſee, that after the phial has received a ſmall charge, a beautiful bruſh of rays will proceed from the cork, which, after going a little way into the air, turns its courſe towards the outſide coating of the phial. If the phial, inſtead of the prime Conductor, be preſented to the inſulated rubber, then the bruſh, inſtead of proceeding from the cork, will iſſue from the outſide coating, and direct its courſe towards the cork or wire of the phial; ſhowing beyond a doubt the truth of the hypotheſis of a ſingle electric fluid.

This experiment, which is of Mr. HENLY, requires a nicety of operation, without which it will not ſucceed as above deſcribed. The quantity of moiſture upon the phial; and the quantity of Electricity communicated by the machine, muſt be of

a degree,

a degree, which nothing but practice can determine.

EXPERIMENT XV.

To make the electric Spark visible in Water.

Fill a glass tube, of about half an inch diameter, and six inches long, with water, and to each extremity of the tube adapt a cork, which may confine the water; through each cork insert a blunt wire; so that the extremities of the wires within the tube may be very near one another; lastly, connect one of these wires with the coating of a small charged phial, and touch the other wire with the knob of it; by which means the shock will pass through the wires, and cause a vivid spark to appear between their extremities within the tube. In performing this experiment care must be taken, that the charge be exceedingly weak, otherwise the tube will burst.

C, fig. 14. Plate II. represents a common drinking-glass almost full of water. AB are two knobbed wires so bent, that their

their knobs may be within a little diſtance of one another in the water. If one of theſe wires be connected with the outſide coating of a pretty large jar, and the other wire be touched with the knob of it; the exploſion which muſt paſs through the water from the knob of one of the wires to that of the other, will diſperſe the water, and break the glaſs with a ſurpriſing violence. This experiment is very dangerous if not conducted with great caution.

F. BECCARIA conſtructed a ſmall mortar, into which a drop of water was put, between the extremities of two wires which went through the ſides of the mortar, and a wooden ball was applied over the drop of water; then a charged jar being diſcharged through the wires of the mortar, and conſequently through the drop of water, rarefied the latter, and drove the ball out with conſiderable force. Mr. LULLIN produced a greater effect by making the diſcharge through oil inſtead of water. *Diſſertatio Phyſica*, p. 26.

EXPERIMENT XVI.

To prove that the electric Spark displaces and rarefies the Air.

Fig. 3. Plate II. represents an instrument, which the inventor, Mr. KINNERSLEY, calls the *electrical Air Thermometer*, it being very useful to observe the effects of the electric explosion upon air. The body of this thermometer consists of a glass tube AB, about ten inches long, and nearly two inches diameter, and closed air-tight at both ends by two brass caps. Through a hole in the upper cap, a small tube HA, open at both ends, is introduced in some water at the bottom B of the large tube. Through the middle of each of the brass caps, a wire FG, EI, is introduced, having a brass knob within the glass tube, and by sliding through the caps, they may be set at any distance from one another. This instrument is, by a brass ring C, fastened to the pillar of the wooden stand CD, that supports it. When the air within the tube

tube AB is rarefied, it will preſs upon the water at the bottom of the tube, which will conſequently riſe in the cavity of the ſmall tube; and as this water riſes higher or lower, ſo it ſhows the greater or leſs rarefaction of the air within the tube A B, which has no communication with the external air.

If the water, when this inſtrument is to be uſed, is all at the bottom of the large tube, (*i. e.* none of it is in the cavity of the ſmall tube) it will be proper to blow with the mouth into the ſmall tube, and thus cauſe the water to riſe a little in it; where, for better regulation, a mark may be fixed.

Bring the knobs GI of the wires IE, FG, into contact with one another, then connect the ring E or F, with one ſide of a charged jar, and the other ring with the other ſide, by which operation a ſhock will be made to paſs through the wires F G, I E, *i. e* between the knobs E I. In this caſe you will obſerve, that the water in the ſmall tube is not at all moved from

the mark; which ſhows, that the paſſage of the electric fluid through Conductors ſufficiently large, occaſions no rarefaction, nor diſplaces the air about them.

Put the knobs G I, a little diſtant from one another, and ſend a ſhock through them as before, and you will ſee that the ſpark between the two knobs, not only diſplaces, but rarefies conſiderably the air; for the water will be ſuddenly puſhed almoſt to the top of the ſmall tube, and immediately it will ſubſide a little, as for inſtance as far as H; which is occaſioned by the ſudden diſplacing and replacing of the air about the place, where the ſpark appeared within the tube A B. After that the water has ſubſided ſuddenly from the firſt riſing, it will then gradually and ſlowly come down to the mark at which it ſtood before the exploſion; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room, where the degree of heat is variable, then proper

proper allowance muſt be made for this circumſtance, in eſtimating the event of the experiment; for the electrical air thermometer is affected by heat or cold in general, as well as by that cauſed by an electric ſpark.

EXPERIMENT XVII.

To fire Gun-powder.

Make a ſmall cartridge of paper, and fill it with gun-powder, or elſe fill the tube of a quill with it; inſert two wires, one at each extremity, ſo that their ends within the quill, or cartridge, may be about one-fifth of an inch from one another; this done, ſend the charge of a phial through the wires, and the ſpark between their extremities, that are within the cartridge or quill, will ſet fire to the gun-powder. If the gun-powder be mixed with ſteel filings, it will take fire more readily, and with a very ſmall ſhock.

EXPERIMENT XVIII.

To light a Candle by the Diſcharge of a Jar.

Take a wire of the ſize of a common knitting-needle, and by means of a ſmall flexible wire or a chain, let one end of it communicate with the outſide of a jar, that at leaſt contains about ten inches of coated ſurface. To the other end of the thick wire ſome cotton muſt be twiſted, but very looſely, ſo as to form a head round, and to conceal the extremity of the wire entirely. This head of cotton muſt be rolled in powder of lycopodium, or, which anſwers better, in powder of roſin; by which means a good deal of the powder will ſtick to the cotton:—this done, the jar is charged, and then the head of cotton, &c. is brought towards its knob rather quickly, ſo as to cauſe the jar to diſcharge through the cotton, by which means the cotton will be inſtantly ſet on fire, and will laſt long enough to light a candle thereby.—This is a very pleaſing experiment, contrived by Dr. INGENHOUZ.

EXPE-

EXPERIMENT XIX.

To ſtrike Metals into Glaſs.

Take two ſlips of common window-glaſs about three inches long, and half an inch wide; put a ſmall ſlip of gold, ſilver, or braſs leaf, between them, and tie them together, or elſe preſs them together between the boards of the preſs H, belonging to the univerſal diſcharger, fig. 5. Plate I. leaving a little of the metallic leaf out of the glaſſes at each end; then ſend a ſhock through this metallic leaf, and the force of the exploſion will drive part of the metal into ſo cloſe a contact with the glaſs, that it cannot be wiped off, or even be affected by the common menſtrua, which otherwiſe would diſſolve it.

In this experiment the glaſſes are often ſhattered to pieces; but whether they are broken or not, the indelible metallic tinge will always be found in ſeveral places, and ſometimes through the whole length of both glaſſes.

Experiment XX.

To ſtain the Paper, or Glaſs.

Lay a chain, which forms a part of the circuit between the two ſides of a charged jar, upon a ſheet of white paper, and if a ſhock be ſent through it, the paper will be found ſtained with a blackiſh tinge at every juncture of the links. If the charge be very great, the paper, inſtead of being ſtained with ſpots, is burnt quite through. If the chain be laid upon a pane of glaſs, inſtead of paper, the glaſs will often be found ſtained with ſpots in ſeveral places, but (as might be expected) not ſo deep as the paper.

If this experiment be made in the dark, a ſpark will be ſeen at every juncture of the links, from which place a kind of radiation alſo proceeds; and if the links are ſmall, and the ſhock pretty ſtrong, the chain will appear illuminated like a line of fire; which ſhows that the electric fluid meets with ſome reſiſtance in paſſing from one link of the chain to another.

EXPERIMENT XXI.

The lateral Explosion.

If a jar be difcharged with a difcharging rod that has no electric handle, the hand that holds it, in making the difcharge, feels fome kind of fhock, efpecially when the charge is confiderable.——In other words: A perfon, or any conducting fubftance, that is connected with one fide of a jar, but forms no part of the circuit, will feel a kind of fhock, *i. e.* fome effect of the difcharge. This may be rendered vifible in the following manner. Connect with the outfide of a charged jar a piece of chain; then difcharge the jar through another circuit, as for inftance, with a difcharging rod in the common way, and the chain that communicates with the outfide of the jar, and which makes no part of the circuit, will appear lucid in the dark, *i. e.* fparks will appear between the links; which fhews that the electric fluid natural to that chain, muft by fome means have been

been diſturbed. This chain will alſo appear luminous, when it is not in contact with the outſide of the jar, but only very near it; and on making the diſcharge, a ſpark will be ſeen between the jar and the end of the chain near it. This electrical appearance out of the circuit of a diſcharging jar, is that which we call the *lateral Exploſion*: and to make it appear in the moſt conſpicuous manner, obſerve the following method, which is of Dr. PRIESTLEY.

When a jar is charged, and ſtands upon the table as uſual, inſulate a thick metallic rod, and place it ſo that one of its ends may be contiguous to the ouſide coating of the jar; and within about half an inch of its other end, place a body of about ſix or ſeven feet in length, and a few inches in breadth; then put a chain upon the table, ſo that one of its ends may be about one inch and a half diſtant from the coating of the jar; to the other end of the chain apply one knob of the diſcharging rod, and bring the other knob to the wire of the jar in order to make the exploſion. On making the diſcharge in this manner, a ſtrong ſpark will be ſeen between

between the inſulated rod, which communicates with the coating of the jar, and the body near its extremity, which ſpark does not alter the ſtate of that body in reſpect to Electricity; hence it is imagined, that this lateral ſpark flies from the coating of the jar, and returns to it at the ſame inſtant, allowing no perceptible ſpace of time, in which an electrometer can be affected. Whether this lateral exploſion is received on flat and ſmooth ſurfaces, or upon ſharp points, the ſpark is always equally long and vivid.

The cauſe of this phenomenon ſeems to be the interruption in the circuit, made by introducing bad Conductors into it; for, as this interruption is greater or leſs, ſo the lateral exploſion is more or leſs conſiderable.

CHAP. VIII.

Experiments with other charged Electrics.

THAT the experiments made with other charged electrics are ſimilar to thoſe made with charged glaſs, is very evident; ſince it has been obſerved in the Firſt Part of this work, and alſo in the experiments already deſcribed, that the property of being charged, of exploding, &c. is not inherent in glaſs, as glaſs, but, as being impervious to the electric fluid; and in conſequence, it muſt be common to all ſuch ſubſtances, which, like glaſs, are impervious to that fluid: therefore, under the title of experiments with other electrics, I mean to deſcribe experiments, not of a different nature from the above-mentioned, but only the manner of coating and uſing other electrics, which are not ſo manageable as glaſs, but at the ſame time, have ſome peculiar advantages. Theſe methods I ſhall reduce to three, *i. e.* firſt, that of making the experiment of charging

charging a plate of air; secondly, the method of coating resinous substances; and lastly, a method of trying other electrics, that are in a fluid state.

EXPERIMENT I.

To charge a Plate of Air.

Take two smooth circular boards, quite plain, and each about three or four feet in diameter; coat one side of each with tin-foil, which should be pasted down, burnished, and turned over the edge of the board. These boards must be both insulated, parallel to one another, in an horizontal position; they must be turned with their coated sides towards each other, and should be placed in such a manner as to be easily moved towards, or from each other; to do which, it will be proper to fix to one of the boards a strong supporter, of glass or baked wood, and to suspend the other by silk strings from the cieling of the room; from which, by a proper pulley, it may be lowered or raised, so as to be at any required distance from the lower board, which may be placed upon a table.

When

When theſe boards are placed in the manner above deſcribed, and at about one inch diſtance from one another, they may be uſed exactly as the two coatings of a pane of glaſs. If one of the boards be connected with the electrified prime Conductor, and the other be left inſulated, they will receive no charge, agreeable to the ſecond experiment of the preceding chapter; and if after ſome time you touch them, you will receive only a ſpark from the upper board, in conſequence of its being connected with the electrified prime Conductor. If, whilſt one of the boards is receiving Electricity, the other communicates with the earth, then the plate of air between them will be charged, like a coated plate of glaſs; for that board which communicates with the earth will acquire an Electricity contrary to that of the other board; and if you touch them, *i. e.* make a communication between them, they will explode, give the ſhock, &c. ſimilar to a charged jar.

In this experiment it cannot be expected, that ſuch an exploſion, and with ſuch a

force, will be produced, as by an equal surface of coated glaſs; for here the coatings cannot be brought ſo near one another as to render them capable of a high charge, becauſe the plate of air, being much leſs compact than glaſs, may be eaſily broken by the force of the charge, *i. e.* it may eaſily diſcharge itſelf. Notwithſtanding, however, that a plate of air is not capable of receiving a very high charge, yet this experiment has a great advantage, which is, that here we may ſee what paſſes between the two coatings, either in charging or diſcharging the plate of air; and we may introduce ſeveral things into the ſubſtance of this coated electric, which produce ſeveral remarkable appearances. By this experiment the true ſtate of the earth, when covered by electrified clouds, may be repreſented exceedingly well; and ſeveral meteors, that happen in that ſtate, and which are thought to be effects of Electricity, may be imitated; ſuch as waterſpouts and whirlwinds, beſides the well-known electrical phenomena, thunder and lightning.

In

In order to repreſent a water-ſpout, as it is often obſerved at ſea, place the two boards at about two inches diſtance from one another; put a large drop of water about the middle of the loweſt of them, and fix a metallic ball, or any other piece of metal that is ſomewhat ſpherical *, to the upper board, juſt oppoſite to, and at about half an inch diſtance from the ſurface of the water. If in this ſituation the upper board be electrified, whilſt the lower communicates with the earth, the water, which repreſents the ſea, will be attracted by the metallic ball, which repreſents a cloud, and riſing nearly in a conical body, will afford a pretty good repreſentation of the water-ſpout †.

The

* The metallic covering of ſome kind of coat-buttons anſwers exceedingly well, and may be paſted on the tin-foil coating of the board.

† The knob of a charged bottle, being brought near the water in a metal plate, or common earthen-ware ſaucer, ſhews this experiment in a ſimple and beautiful manner; If a large drop of water be placed upon the knob of an inſulated charged bottle, and the knob of another bottle, charged with the contrary Electricity, be brought near the drop of water, it will be ſquirted

The appearance of a whirlwind is but ſeldom, and by chance to be obſerved, The bran between the two plates, F, P, fig. 2. Plate I, is ſometimes whirled like the duſt in a whirlwind; but there is no certain rule, that I know, for producing this phenomenon.

In order to ſucceed in this experiment, Mr. BECKET directs to place the boards above-mentioned about four or five inches aſunder, and to put ſome bran, and very ſmall bits of paper, about the center of the lower board. If in this ſituation the upper board be connected with the electrified prime Conductor, and the lower one be either connected with the ground or with the rubber of the machine, the bran, and bits of paper, will be attracted and repelled, alternately, by the boards. " But (ſays Mr. BECKET*) " the moſt ſurpriſing ap-
" pearance in this experiment, and what
" gives it the moſt exact reſemblance of a

ſquirted away in a curious manner, particularly if the coating of the inſulated bottle be touched at the ſame time.

* In his Eſſay on Electricity, p. 141.

"whirlwind, is that ſometimes, when the "Electricity is very ſtrong, a quantity of "the paper and bran will accumulate in "one place, forming a kind of column "between the boards, and ſuddenly ac-"quire a ſwift horizontal motion, moving "like a whirling pillar to the edge of the "boards, and from thence fly off, and be "ſcattered about the room to a conſider-"able diſtance. I own I am entirely at a "loſs to account for this extraordinary ap-"pearance—I call it extraordinary, be-"cauſe it but ſeldom occurs, and ſeems to "depend either on a certain degree of at-"traction, quantity of the bran, or diſ-"tance between the boards; and I could "ſeldom get it to ſucceed perfectly but by "accident."

The phenomena of thunder and lightning are exhibited at the ſame time by a ſpontaneous diſcharge of the plate of air; which may be eaſily produced by ſetting the boards at about an inch diſtance from each other, and electrifying them ſtrongly.

EXPE-

EXPERIMENT II.

To coat resinous Electrics.

The best method to coat such electrics as rosin, sealing-wax, &c. that can easily be melted, is first to put a circular piece of tin-foil, about two inches less in diameter than the plate you intend to make, upon a marble table; then, to pour over it the electric just melted. This may be spread and flattened by pressing it with a pane of glass, or any thing that is even and smooth; afterwards, another piece of tin-foil, equal to the former, is to be stuck upon the electric, which may be done by pressing it gently with a hot iron; and then the plate, which, when cold, may be easily separated from the marble table, will be fit for use.

EXPERIMENT III.

To insulate fluid Electrics.

Take a large earthen dish, flat at the bottom, and stick within it a piece of tin-

 foil

foil about an inch ſhorter than the flat part of the diſh all round, and through a ſmall hole, made in the bottom of the diſh, introduce a ſlender wire, which muſt communicate with the tin-foil; then pour into the diſh ſome melted tallow, or other electric ſubſtances that you deſire to try; laſtly, let a round braſs plate*, equal to the tinfoil ſtuck in the diſh, and either proceeding from a glaſs arm or from the prime Conductor, juſt touch the ſurface of the electric in the diſh, and let it ſtand parallel, and oppoſite to the tin-foil ſtuck in its bottom. In this manner the plate of liquid electric is coated, and may be eaſily ſubjected to experiments.

Plates of other conſiſtent electrics, that cannot eaſily be melted, may be coated in the ſame manner as a plate of glaſs; and ſome of them will be found to anſwer as well, if not better than glaſs.

* The braſs plate F, fig. 2. of Plate I. may be very uſeful for this purpoſe.

CHAP.

CHAP. IX.

Experiments on the Influence of Points, and the Uſefulneſs of pointed metallic Conductors, to defend Buildings from the Effects of Lightning.

MY reader, in the courſe of this work, muſt have obſerved in ſeveral of the experiments already deſcribed, the remarkable property that points have, both of throwing off and receiving *ſilently* the electric fluid; but in this chapter I ſhall deſcribe ſome more curious experiments of this kind, by which the influence of points, in reſpect to Electricity, may be better underſtood, and which may, in a more particular manner, demonſtrate the utility of metallic Conductors to houſes, or piles of building, in order to preſerve them from the damage often occaſioned by a ſtroke of lightning; which is one of the greateſt benefits that mankind has received from the ſcience of Electricity.

EXPERIMENT I.

To difcharge a Jar filently.

When a large jar is fully charged, which would give a terrible fhock, put one of your hands in contact with its outfide coating; with the other hold a fharp-pointed needle, and, keeping the point directed towards the knob of the jar, proceed gradually towards it, until the point of the needle touches the knob. This operation difcharges the jar entirely, and you will either receive no fhock at all, or fo fmall a one as can hardly be perceived. The point of the needle, therefore, has filently and gradually drawn all the fuperfluous fluid from the infide furface of the electric jar.

EXPERIMENT II.

Drawing the Electricity from the prime Conductor by a Point.

Let a perfon hold the knob of a brafs rod at fuch a diftance from the prime Conductor, that fparks may eafily fly from the latter to the former, when the machine is in motion. Then let the winch be turned, and, while the fparks are following one another, prefent the fharp point of a needle, at nearly

twice

twice the diſtance from the prime Conductor that the knobbed rod is held; and you will obſerve that no more ſparks will go to the rod;—remove the needle entirely, and the ſparks will be ſeen again;—preſent the needle, and the ſparks diſappear; which evidently ſhows, that the point of the needle draws off *ſilently* almoſt all the fluid that the cylinder throws upon the prime Conductor. If whilſt the pointed needle ſtands preſented to the Conductor you form the finger and thumb of your hand like a ring, and ſurround the point of the needle, its action will be ſuppreſſed, as is manifeſted by the ſparks which go to the rod, which ſhews that a point will act as a point only whilſt it remains free and diſencumbered; but not when ſurrounded by other bodies.

If the needle be fixed upon the prime Conductor with the point outward, and the knob of a diſcharging rod, or the knuckle of a finger, be brought very near the prime Conductor, though the excitation of the cylinder may be very ſtrong, yet you will perceive that no ſpark, or only an exceeding ſmall one, can be obtained from the prime Conductor.

Experiment III.

The electric Fly.

Fix the fly, described in the third chapter, upon the prime Conductor, as represented by D, fig. 2, of Plate I; then turn the winch of the machine, and the fly will immediately begin to move round in an horizontal position, and in the direction of the letters *a b c d*; *i. e.* contrary to the direction of the points of the wires. If the experiment be repeated with a Conductor negatively electrified, the fly will turn the same way as before, *viz.* in the direction of the letters *a b c d*. The reason of this experiment depends upon the repulsion existing between bodies possessed of the same Electricity; for whether the fly is electrified positively or negatively, the air opposite to the points of the wires (on account of the points easily transmitting Electricity) acquireth a strong Electricity, analogous to that of the points; and therefore the air and the points must repel each other. This explanation is confirmed, by observing

observing that the above fly not only does not move in vacuo; but even, if placed under a close receiver, it will turn but for a little while, and then stop; for the quantity of air contained in the receiver, may become readily, and equally electrified *.

EXPERIMENT IV.

The electrified Cotton.

Take a small lock of cotton, extended in every direction as much as can conveniently be done, and by a linen thread about

* If, when the fly under the close receiver is stopped, you put the end of a finger on the outside of the glass, opposite to one of the points of the fly, this will move again briskly; and by altering the position of your finger occasionally round the glass, you may continue its action a considerable time, *viz.* till most of that part of the glass is charged. In this case, when the finger is applied on the outside of the receiver, the glass losing part of its natural electric fluid from the outside (*i. e.* when the fly is electrified positively, or *vice versa*, when negatively) receives the fluid of the electrified air on its inside surface; hence this air is put in a state of being again electrified by the point of the fly, which renews the motion.

five

five or ſix inches long, or by a thread drawn out of the ſame cotton, tie it to the end of the prime Conductor; then let the winch of the machine be turned, and the lock of cotton, on being electrified, will immediately ſwell, by repelling its filaments from one another, and will ſtretch itſelf towards the neareſt Conductor. In this ſituation let the winch be kept turning, and preſent the end of your finger, or the knob of a wire, towards the lock of cotton, which will then immediately move towards the finger, and endeavour to touch it; but take with the other hand a pointed needle, and preſent its point towards the cotton, a little above the end of the finger, and you will obſerve the cotton immediately to ſhrink upward, and move towards the prime Conductor. Remove the needle, and the cotton will come again towards the finger. Preſent the needle, and the cotton will ſhrink again: which clearly ſhews, that the needle, being ſharp-pointed, draws off the electric fluid from the cotton, and puts it in a ſtate of being attracted by the prime Conductor; which could not be effected by a wire having a blunted

blunted end, or a round ball for its termination.

EXPERIMENT V.

The electrified Bladder.

Take a large bladder, well blown, and cover it with gold, ſilver, or braſs leaf, ſticking it with gum-water; ſuſpend this bladder at the end of a ſilk thread, at leaſt ſix or ſeven feet long, hanging from the cieling of the room, and electrify the bladder, by giving it a ſtrong ſpark with the knob of a charged bottle: this done, take a knobbed wire, and preſent it to the bladder when motionleſs, and you will perceive, that as the knob approaches the bladder, the bladder alſo moves towards the knob, and when nearly touching it, gives it the ſpark, which it received from the charged phial, and thus it becomes unelectrified. Give it another ſpark, and, inſtead of the knobbed wire, preſent the point of a needle towards it, and you will perceive that the bladder will not be attracted by, but rather recede from the

point,

point, especially if the needle be very suddenly presented towards it.—This is one of Mr. HENLY's experiments.

Before we proceed to the practical use of pointed Conductors to buildings, in order to defend them from lightning (which is nothing more than the proper application of the preceding experiments) it will be proper to say something in explanation of the above property of points, which a few years ago occasioned several controversies. In order to this, it should be remembered, that the electric fluid superinduced upon an insulated body, is confined upon that body by the air which surrounds it. Further, that Electricity, by being continually communicated to the air, which is never a perfect electric, is gradually dissipated; from whence follows this very evident principle, *i. e.* that as a greater or less quantity of air is contiguous to a given quantity of electrified surface, so that surface loseth its Electricity sooner or later. Suppose, for instance, that a pointed needle is fixed upon the prime Conductor; mark a dot upon any part of the prime Conductor,

tor, which may be nearly equal to the point of the needle, and then electrify the prime Conductor. Now it is evident to bare inspection, that although the point of the needle and the dot, &c. are of equal surfaces, yet the former is exposed to a quantity of air, which almost entirely surrounds it, and which is vastly greater than the air contiguous to the latter: hence, the Electricity, communicated to the prime Conductor, is dissipated more easily from the point of the needle than from the dot, or any other part of the prime Conductor. Besides, the air about the point may more easily be moved, in consequence of the electrical repulsion, than at any other part of the surface of the prime Conductor, and new air, *i. e.* unelectrified air, passes more frequently by it, which taking always part of the Electricity of that body, promotes also its dissipation.

In the same manner may be understood, why the Electricity is more easily dissipated at sharp edges and corners, than at flat ones; for as the surfaces of bodies in general are more or less plain, so they are

exposed

expoſed to a leſs or greater quantity of air and participate more or leſs of the nature and properties of points.

When the pointed body is negatively electrified, it is for the ſame reaſon that it acquires the electric fluid through the point, eaſier than through any other part of its ſurface; *i. e.* becauſe the point exhibiting the leaſt ſurface to the greateſt quantity of free air, has the greateſt number of particles of air, from which it can extract the electric fluid*.

EXPERIMENT VI.

The Thunder-houſe.

Fig. 1. of Plate II. is an inſtrument repreſenting the ſide of a houſe, either furniſhed with a metallic Conductor, or not; by which both the bad effects of lightning ſtriking upon a houſe not properly ſecured, and the uſefulneſs of metallic Con-

* For a more particular explanation of the above-mentioned property of points, ſee BECCARIA's Artificial Electricity.

ductors,

ductors, may be clearly represented. A is a board about three-quarters of an inch thick, and shaped like the gable-end of a house. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glass pillar CD is also fixed, in a hole about eight inches distant from the basis of the board A. A square hole, ILMK, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a square piece of wood, nearly of the same dimensions. I mention nearly of the same dimensions, because it must go so easily into the hole, that it may drop off by the least shaking of the instrument. A wire, LK, is fastened diagonally to this square piece of wood. Another wire, IH, of the same thickness, having a brass ball, H, screwed on its pointed extremity, is fastened upon the board A; so also is the wire MN, which is shaped in a ring at O. From the upper extremity of the glass pillar CD, a crooked wire proceeds, having a spring socket F, through which a double-knobbed wire slips perpendicularly, the lower knob G of which falls just

above the knob H. The glaſs pillar DC muſt not be made very faſt into the bottom board; but it muſt be fixed ſo as to be pretty eaſily moved round its own axis, by which means the braſs ball G may be brought nearer or farther from the ball H, without touching the part EFG. Now when the ſquare piece of wood LMIK (which may repreſent the ſhutter of a window or the like) is fixed into the hole ſo, that the wire LK ſtands in the dotted repreſentation IM, then the metallic communication from H to O, is complete, and the inſtrument repreſents a houſe furniſhed with a proper metallic Conductor; but if the ſquare piece of wood LMIK is fixed ſo, that the wire LK ſtands in the direction LK, as repreſented in the figure, then the metallic Conductor HO, from the top of the houſe to its bottom, is interrupted at IM, in which caſe the houſe is not properly ſecured.

Fix the piece of wood LMIK, ſo that its wire may be as repreſented in the figure, in which caſe the metallic Conductor HO is diſcontinued. Let the ball G

be fixed at about half an inch perpendicular distance from the ball H, then, by turning the glaſs pillar DC, remove the former ball from the latter: by a wire or chain connect the wire EF with the wire Q of the jar P, and let another wire or chain, faſtened to the hook O, touch the outſide coating of the jar. Connect the wire Q with the prime Conductor, and charge the jar; then, by turning the glaſs pillar DC, let the ball G come gradually near the ball H, and when they are arrived ſufficiently near one another, you will obſerve that the jar explodes, and the piece of wood, LMIK, is puſhed out of the hole to a conſiderable diſtance from the thunder-houſe. Now the ball G, in this experiment, repreſents an electrified cloud; which, when it is arrived ſufficiently near the top of the houſe A, the Electricity ſtrikes it, and, as this houſe is not ſecured with a proper Conductor, the exploſion breaks part of it, *i. e.* knocks off the piece of wood IM.

Repeat the experiment with only this variation, *viz.* that this piece of wood IM

is ſituated ſo, that the wire LK may ſtand in the ſituation IM; in which caſe the Conductor HO is not diſcontinued; and you will obſerve, that the exploſion will have no effect upon the piece of wood LM; this remaining in the hole unmoved; which ſhews the uſefulneſs of the metallic Conductor.

Further: Unſcrew the braſs ball H from the wire HI, ſo that this may remain pointed, and, with this difference only in the apparatus, repeat both the above experiments; and you will find that the piece of wood IM is in neither caſe moved from its place, nor any exploſion will be heard; which demonſtrates the preference of Conductors with pointed terminations to thoſe with blunted ones.

To prove farther the preference of pointed Conductors to blunt ones, the experiment of the electrified cotton (*viz.* the fourth experiment of this chapter) may be eaſily repeated with this apparatus; by which it may be ſhewn, that a pointed Conductor ſilently drawing off the electric fluid from the

the ſmall clouds near it, which are repreſented by the cotton tied to the wire of the ball G, repels them, and may thus, in ſome caſes, perhaps, actually prevent a ſtroke of lightning; whereas the blunted Conductor facilitates it. Small feathers may alſo be tied near the knob G, which, by repelling one another, may exhibit a better repreſentation of an electrified cloud; and, in ſhort, with a little contrivance, the above-deſcribed apparatus, commonly called the *Thunder-houſe*, may be adapted to repreſent the principal phenomena of lightning, together with ſeveral circumſtances preceding, or following it.

CHAP. X.

Experiments with the electrical Battery.

THE force of accumulated Electricity, great as it appears by the experiments performed with a single coated jar, is very small when compared with that, which is produced by a number of jars connected together; and if the effects of a single jar are surprising, the prodigious force of a large battery is certainly astonishing. To observe that the metals, even the most purified platina, which resists the greatest efforts of chemic fire, are actually, and almost instantaneously rendered red-hot, and fused; to see animals destroyed; and to hear the loud report of a large electric battery, are things that always produce a kind of terror in the mind of an attentive observer. Experiments of this kind should be conducted with great caution, and the Operator ought to be attentive, not only to the business in hand, but also to the persons who may happen to be near him, prohibiting their touching, or even coming too near any part of the apparatus; for if a mistake in performing other experiments may

may be diſagreeable, thoſe in the diſcharge of a large battery may be attended with worſe conſequences.

When a battery is to be charged, inſtead of a large prime Conductor, a ſmall one is much more convenient; for, in this caſe, the diſſipation of the Electricity is not ſo conſiderable. The quadrant electrometer, which ſhews the height of the charge in the battery, may be fixed either upon the prime Conductor, or upon the battery; in which latter caſe, it ſhould be placed upon a rod proceeding from the wires of the jars, and if the battery be very large, it ſhould be elevated two or three feet above them. Even in common uſe, *viz.* when placed upon the prime Conductor, as ſhewn in fig. 2. Plate I. the quadrant electrometer ſhould be elevated ſome inches above the ſurface of the Conductor.

The index of the electrometer in charging a large battery will ſeldom riſe ſo high as 90°, becauſe the machine cannot charge a battery ſo high in proportion, as a ſingle jar. Its limit is often about 60° or 70°,

 more

more or leſs in proportion to the ſize of the battery, and the force of the machine.

Experiment I.

To melt Wires.

Connect with the hook, communicating with the outſide coating of a battery, containing at leaſt thirty ſquare feet of coated ſurface, a wire, that is about one-fiftieth part of an inch thick, and about two feet long; the other end of it muſt be faſtened to one end of the diſcharging rod; this done, charge the battery, and then, by bringing the diſcharging rod near its wires, ſend the exploſion through the ſmall wire, which, by this means, will be made red-hot, and melted, ſo as to fall upon the floor in different glowing pieces. When a wire is melted in this manner, ſparks are frequently ſeen at a conſiderable diſtance from it, which are red-hot particles of the metal, that by the violence of the exploſion are ſcattered in all directions. If the force of the battery is very great, the wire will be intirely diſperſed by the exploſion, ſo that none of it can be afterwards found.

By

By repeating this experiment with wires of different metals, and the ſame force of exploſion, it will be found that ſome metals are more readily fuſed than others, and ſome not at all affected; which ſhows the difference of their conducting power. If it be required to melt ſuch particles of metals, that cannot eaſily be drawn in wires, as ores, grains of platina, &c. they may be ſet in a train upon a piece of wax; this train may be inſerted in the circuit, and an exploſion may be ſent through it, which, if it be ſufficiently ſtrong, will melt the metallic particles, as well as the wires: or, if the quantity to be tried be large enough, it may be confined in a ſmall tube of glaſs.

In melting wires of a conſiderable length, it is often obſerved, that when the force of the exploſion is juſt ſufficient to render the wire red-hot, the redneſs begins firſt from one end of it, namely, that which communicates with the poſitive ſide of the battery, and from thence gradually proceeds to the other end. This is another ocular demonſtration of the theory of a ſingle electric fluid. Indeed the wire is not rendered red-

hot in one place before the other, in consequence of the electric fluid passing first through the former, and then through the latter, for that difference of time is by far too small to be observed; but, because the electric fluid loses some of its impetus, or velocity, in going through the wire; hence the part of the wire which the electric fluid enters, suffers the greatest effect of the shock, and, consequently, becomes red sooner, and in a greater degree.

If a wire be stretched by weights, and a shock be sent through it, which renders it just red-hot, the wire, after the explosion, will be found considerably lengthened; but if the wire be left loose, after a similar explosion it will be found shortened*. If a wire be melted upon a piece of glass, the glass, after the explosion, will be found marked with all the prismatic colours.

* This is a late observation of Mr. Edward Nairne. See the Phil. Transf. vol. LXX.

EXPERIMENT II.

To ſhew that the electric Fluid prefers a ſhort Paſſage through the Air, to a long one through good Conductors.

Bend a wire about five feet long in the form repreſented by fig. 11. Plate II. ſo that the parts AB may come within half an inch of one another; then connect the extremities of the wire with the hook of the battery, and the diſcharging-rod, as directed in the preceding experiment, and ſend the charge of a battery through it. On making the exploſion, a ſpark will be ſeen between A and B, which ſhows that the electric fluid chooſes rather a ſhort paſſage through the air, than the long one through the wire. The charge, however, does not paſs intirely through A and B, but part of it goes alſo through the wire; which may be proved by putting a ſlender wire between A and B; for, on making the diſcharge with only this addition in the apparatus, the ſmall wire will be hardly made red-hot; whereas, if the large wire ADB be

be cut in D, ſo as to diſcontinue the circuit ADB, the ſmall wire will be melted, and even exploded, by the ſame ſhock that before made it ſcarcely red-hot. In this manner (ſays Dr. PRIESTLEY, who is the inventor of this experiment) may the conducting power of different metals be tried, uſing metallic circuits of the ſame length and thickneſs, and obſerving the difference of the paſſage through the air in each.

EXPERIMENT III.

To make Globules of Metals.

Take a very ſlender wire, and put it in a glaſs tube, about one quarter of an inch in diameter; then ſend the charge of a battery through it, and the wire will be melted, and reduced into globules of different ſizes, which are found ſticking on the inſide ſurface of the glaſs tube, and they may be eaſily ſeparated from it at pleaſure: theſe, upon examination, will all be found hollow, and are little more than a mere ſcoria of the metal.

It muſt be obſerved, in making this experiment, that the charge of the battery muſt neither be too high nor too weak; for in the former caſe, the wire will be reduced into pieces exceedingly ſmall, or rather exploded in ſmoke; and in the latter caſe, it will be imperfectly fuſed, ſo that its pieces will be large and irregular.

EXPERIMENT IV.

The Fairy Circles.

Fix upon each of the knobs DD of the univerſal diſcharger, fig. 5. Plate I. or upon the wires that ſupport the knobs, when the knobs are removed, a flattiſh and ſmooth piece of metal, or ſemi-metal (watch-caſes are very fit for this purpoſe) ſo that their ſurfaces may come ſo near each other, that the battery may be diſcharged through them; then connect one wire of the diſcharger with the outſide of the battery, and the other wire, by the help of the diſcharing-rod, with the inſide of it, ſo as to make the diſcharge; which will occaſion the ſpot and circles deſcribed in the

the firſt part of this Treatiſe, upon the ſurface of each of the pieces of metal fixed upon the diſcharger.

Theſe circles have hitherto been exhibited upon the ſurface of no other ſubſtances but metals; and they are found to be marked more diſtinctly upon ſuch metals as melt with the leaſt heat. The moſt beautiful of theſe rings are produced by a number of diſcharges repeatedly taken from a large battery, every part of the apparatus remaining exactly in the ſame ſituation. If the pieces of metal receive the exploſion in vacuo, the ſpot formed on them is very irregular and confuſed.

I have given theſe ſpots the appellation of *Fairy Circles*, on account that they bear ſome reſemblance to the ſpots ſo called, which are often obſerved upon the graſs in the fields. Theſe, which we may call natural Fairy Circles in the fields, have been thought to be effected by lightning, on account of their bearing ſome reſemblance to the above-mentioned circles produced by Electricity; the ſuppoſition, however,

however, ſeems not very probable; for the ſpots in the fields, called Fairy Circles, have no central ſpot, no concentric circles, neither are they always of a circular figure; and, as I am informed, they ſeem to be rather beds of muſhrooms than the effects of lightning.

EXPERIMENT V.

To mark coloured Rings on Metals.

In order to exhibit coloured rings upon the ſurface of metals, place a plain piece of any of the metals upon one of the wires of the univerſal diſcharger, and upon the other wire fix a ſharp-pointed needle, with the point juſt oppoſite to the ſurface of the metal; then connect one wire of the diſcharger with the outſide of a battery, and the other with the diſcharging-rod, &c. In this manner, if exploſions be repeatedly ſent either from the point to the piece of metal, or from the latter to the former, they will gradually mark the ſurface of the piece of metal oppoſite to the point, with circles, conſiſting of all the priſmatic

prismatic colours; which are evidently occasioned by laminæ of the metal, raised by the force of the explosions.

These colours appear sooner, and the rings are closer to one another, when the point is nearer to the surface of the metal. The number of rings is greater or less, according as the point of the needle is more sharp or more blunt; and they are represented equally well upon any of the metals.

The point of the needle is also coloured to a considerable distance; the colours upon it returning in circles, though not very distinctly. This is an experiment of Dr. Priestley.

Experiment VI.

The Imitation of an Earthquake.

The appearance of the earthquake, as represented with the explosion of a battery, is occasioned by the concussion given to several substances by the explosion passing

paſſing over their ſurfaces. To give a repreſentation of the impreſſion made upon houſes by the earthquake, ſmall ſticks, cards, or the like, may be placed upon the ſurface of the body over which the exploſion is to be tranſmitted, ſo as to ſtand very light. Theſe ſticks, &c. will never fail to be ſhook, and often to be thrown down by the exploſion.

It is remarkable, that an exploſion will not paſs over the ſame length of ſurface of all bodies, though they are equally good Conductors. Water, ice, wet wood, raw fleſh, and moſt of the animal fluids, are the beſt to make this remarkable experiment; to do which, nothing more is required than to inſert part of the ſurface of the ſaid ſubſtances into the circuit of the two ſides of a battery; a chain, for inſtance, communicating with the outſide, may be placed ſo as nearly to touch the ſurface of a quantity of water, and at about eight or nine inches diſtant * from another

* The diſtance at which an exploſion will ſtrike over the ſurface of the above-mentioned ſubſtances, is much greater than that it can ſtrike through in air only.

chain,

chain, ſituated alſo very near the ſurface of the water, and communicating with one end of the diſcharging-rod. If the ends of the chains touch the water, the experiment will happen in the ſame manner.

The report, in this experiment, is much louder than when the exploſion paſſes through the air only. The concuſſion given to the water, by the exploſion paſſing over its ſurface, is not only ſuperficial, but affects its whole body; and if the hand be kept deep under its ſurface whilſt the exploſion paſſes over it, the concuſſion may be very ſenſibly felt.

The ſpark, which in this experiment paſſes over the ſurface of the water, ſeems to bear a great reſemblance to the balls of fire that have ſometimes been ſeen over the ſurface of the ſea or land in time of an earthquake; and hence it ſeems very probable, that thoſe balls of fire are electrical phenomena.

CHAP. XI.

Promiſcuous Experiments.

EXPERIMENT I.

To ſhew that Smoke, and the Vapour of hot Water, are Conductors.

LET a cork-ball electrometer be ſuſpended about four or five feet above the prime Conductor, then turn the winch of the machine very gently, and you will find, that the balls of the electrometer will not diverge. Put upon the prime Conductor a wax-taper * juſt blown out, ſo that its ſmoke may aſcend to the electrometer; then turn the winch again, and the balls of the electrometer will immediately ſeparate a little, with the ſame force of Electricity, from the prime Conductor; which ſhows that ſmoke is a Conductor in a ſmall degree.

* A green wax-taper is the beſt for this experiment.

In the ſame manner, by placing a ſmall veſſel with hot water upon the prime Conductor, inſtead of the wax-taper, it may be proved, that its vapour is alſo a Conductor; but inferior in its conducting power to the ſmoke. This experiment is an invention of Mr. HENLY.

EXPERIMENT II.

To prove that Glaſs, and other Electrics, become Conductors, when they are made very hot.

Take a ſmall glaſs tube of about one-twentieth of an inch in diameter, and above a foot long; cloſe it at one end, and introduce a wire into it, ſo that it may be extended through its whole length: let two or three inches of this wire project above the open end of the tube, and there faſten it with a bit of cork; tie round the cloſed end of the tube another wire, which will be ſeparated from the wire within the tube only by the glaſs interpoſed between them. In theſe circumſtances endeavour to ſend a ſhock through the two wires;

i. e.

i. e. the wire inſerted in the glaſs tube, and that tied on its outſide, by connecting one of them with the outſide, and touching the other with the knob of a charged jar, and you will find that the diſcharge cannot be made, unleſs the tube be broken; becauſe the circuit is interrupted by the glaſs at the end of the tube, which is interpoſed between the two wires. But put that end of the tube to which the wire is tied into the fire, ſo that it may become juſt red-hot, then endeavour to diſcharge the jar again through the wires, and you will find that the exploſion will be eaſily tranſmitted from wire to wire, through the ſubſtance of the glaſs, which, by being made red-hot, is become a Conductor.

In order to aſcertain the conducting quality of hot reſinous ſubſtances, oils, &c. bend a glaſs tube in the form of an arch CEFD, fig. 7. Plate II. and tie a ſilk ſtring GCD to it, which ſerves to hold it by when it is to be ſet near the fire; fill the middle part of this tube with roſin, ſealing-wax, &c. then introduce two wires AE, BF, through its ends, ſo that they

may touch the rosin, or penetrate a little way in it. This done, let a person hold the tube over a clear fire, so as to melt the rosin within it; at the same time, by connecting one of the wires, A or B, with the outside of a charged jar, and touching the other with the knob of the jar, endeavour to make the discharge through the rosin, and you will observe that, while the rosin is cold, no shocks can be transmitted through it; but it becomes a Conductor according as it melts, and when totally melted, the shocks will pass through it very freely.

Experiment III.

To shew that hot Air is a Conductor.

Electrify one of the cork-ball electrometers suspended upon the stand, fig. 4. of Plate I. or electrify the prime Conductor with the quadrant electrometer; then bring a red-hot iron within a sufficient distance of the electrometer, or prime Conductor, and you will find that they soon lose their Electricity, which is certainly

tainly conducted by the hot air contiguous to the iron; for if the experiment be repeated with the same iron when cold, *i. e.* by bringing it within the same distance of the electrified Electrometer, or prime Conductor, their Electricity will not be conducted away as before*.

The above experiments may reasonably induce us to suspect, that several substances which are ranged among Conductors, would become Electrics, if they were brought into a cold temperature; and that all the Electrics become Conductors, when they are heated to a very high degree.

* It has been often observed, that a battery may be discharged, by introducing a red-hot iron between two knobs interposed, and standing at some distance from each other in the circuit; but if, instead of iron, there be introduced a piece of red-hot glass between the knobs (the distance between them remaining as at first) the battery cannot be discharged: whence we may infer, that either hot air is not so good a Conductor as has been imagined, or else, that air heated by iron (perhaps from its ignited particles) is stronger, with respect to its conducting power, than when heated by the red-hot glass.

EXPERIMENT IV.

To ſhew that Silks of different Colours acquire different Electricities.

Lay a white ribbon upon another ribbon of the ſame ſize and fineneſs, but black; then holding them by one extremity with one hand, draw them ſwiftly between the firſt and ſecond finger of the other hand, by which friction they will be both electrified, and on being ſeparated, the black ribbon will be found to be negative, and the white, poſitive.

EXPERIMENT V.

To electrify the Air of a Room.

The air ſurrounding the electrical machine when in uſe, or contiguous to every highly-electrified body, always acquires a portion of Electricity, which it retains for a conſiderable time, and which, in ſome meaſure, counteracts the Electricity of electrified

trified bodies *. A very expeditious method, however, to electrify the air, is to fix two or three needles upon the prime Conductor, and to keep it ſtrongly electrified for about ten minutes. If afterwards an electrometer be brought into the air ſurrounding the apparatus, it will plainly ſhew, that the air has acquired a conſiderable quantity of Electricity, which it will retain even after the apparatus has been removed into another room. To electrify the air negatively, connect the pointed needles with the rubber when inſulated; and make a communication by a chain, or wire, from the prime Conductor to the table.

Another method of electrifying the air is, to charge a large jar, and inſulate it: then connect a ſharp-pointed wire, or a number of them, with the knob of the jar; and make a communication from the outſide coating to the table. If the jar be charged poſitively, the air of the room will ſoon become ſtrongly electrified poſitively

* An electrometer ſuſpended to the prime Conductor, will diverge moſt after a few turns of the wheel; but afterwards the divergence will leſſen, according as the air about the apparatus becomes electrified.

likewiſe; but if the jar be charged negatively, the air will become alſo negative. A charged jar being held in one hand, and the flame of a candle, inſulated, and held in the other, being brought near the knob of the jar, will alſo ſoon produce the ſame effect.

EXPERIMENT VI.

The Atmoſphere of Smoke.

Take a braſs ball, or any piece of metal that is free from points or edges, of about three or four inches diameter, and inſulate it upon a narrow electric ſtand; then give it a ſpark with the knob of a charged phial, and immediately preſent to it a wax-taper juſt blown out and ſmoking. The ſmoke, in this caſe, will be attracted by the electrified body, and, by encompaſſing that body will form a kind of atmoſphere about it. This atmoſphere will remain for a few ſeconds, and afterwards, beginning from the bottom, will gradually vaniſh, until at laſt, entirely departing from the electrified body, it goes off in a ſlender column, that ſoon rarefies, and diffuſes itſelf into a conſiderable ſpace.

This experiment will not ſucceed, unleſs it be made in very dry weather, and in a room where the air is not agitated. Care muſt alſo be taken, that, in blowing out the taper, and preſenting it to the electrified body, the air be diſturbed as little as poſſible.

This phenomenon has induced ſome philoſophers to ſuppoſe, that the Electricity of an electrified body reſided about it, *i. e.* reſted upon its ſurface like an atmoſphere; which, they thought, was made very evident by the ſmoke. But this appearance, when duly conſidered, is far from proving any ſuch electric atmoſphere; and the cauſe of it may be very eaſily explained in the following manner:—The ſmoke is attracted by the electrified body in the ſame manner, and for the ſame reaſon, that other bodies are attracted by it. It remains ſuſpended about that body, and cannot all come into contact with its ſurface, on account of the elaſticity of its particles. It remains ſo long ſuſpended about the electrified body, and is not immediately repelled, becauſe it is a

bad

bad Conductor, and acquires Electricity very ſlowly; but, having acquired a ſufficient quantity of Electricity, it begins to quit the electrified body, and, aſcending in the air, extends itſelf into a large ſpace, in conſequence of the repulſion exiſting between its own electrified particles.

EXPERIMENT VII.

To ſhew that Metals conduct the electric Fluid through their Subſtance.

Take a wire of any kind of metal, and cover part of it with ſome electric ſubſtance, as roſin, ſealing-wax, &c. then diſcharge a jar through it, and it will be found, that it conducts as well with, as without, the electric coating. This proves that the electric fluid paſſes through the ſubſtance of the metal, and not over its ſurface.

EXPERIMENT VIII.

The electrified Cup and Chain.

Insulate a metallic cup, or any other concave piece of metal, and place within it a pretty long metallic chain, having a silk thread tied to one of its ends. To the handle of the cup, or to a wire proceeding from it, suspend a cork-ball electrometer; then electrify the cup, by giving it a spark with the knob of a charged phial, and the balls of the electrometer will immediately diverge. If, in this situation, one end of the chain be gradually raised up above the top of the cup, &c. by the silk thread, while the lower end of the chain remains in it, the balls of the electrometer will converge a little, and more or less in proportion to the elevation of the chain above the top of the vessel; which proves that the Electricity of the cup and chain together is more dense when these bodies are in a compact, than when they are in a more extended form. A more easy method of shewing

ſhewing this property of Electricity, is that uſed by T. Ronayne, Eſq; which is as follows:—He excites a long ſlip of white flannel, or a ſilk ribband, by rubbing it with his fingers; then, by applying his hand to it, takes off as many ſparks as the excited electric will give; but when the flannel, &c. has loſt the power of giving any more ſparks in this manner, he doubles, or rolls it up; by which operation the contracted flannel, &c. appears ſo ſtrongly electrical, that it not only gives ſparks to the hand brought near, but it throws out ſpontaneous bruſhes of light, which appear very beautiful in the dark.

Experiment IX.

To ſhew the Courſe of the electric Fluid by the Flame of a Wax-taper.

Fix at that extremity of the prime Conductor which is the remoteſt from the machine, a braſs rod ſix inches long, having on its extremity a braſs ball about three-fourths of an inch in diameter, and let the winch of the machine be turned.

If

If in this ſituation the flame of a wax-taper be preſented to the above-mentioned braſs ball, it will be blown almoſt horizontally, and in a direction from the ball; that is, in the direction of the electric fluid. If a wire, with a like ball, be fixed to the inſulated rubber, the flame of a wax-taper, preſented to this ball, will be blown alſo in the direction of the electric fluid; that is, it will be blown upon the ball, ſhewing the true courſe of the electric fluid in a very ſimple and convincing manner.

EXPERIMENT X.

To ſhew the electric Attraction and Rupulſion by the electric Light.

Fix a pointed wire upon the prime Conductor with the point outward, and another like wire upon the inſulated rubber; then let the winch of the machine be turned, and the points of both wires will appear illuminated, *viz.* the former with a bruſh, and the latter with a ſtar. In this ſituation, take an excited glaſs tube, and bring

it ſideway of the point of the wire fixed upon the prime Conductor, and you will ſee that the bruſh of rays iſſuing from the point, is turned ſideway, *i. e.* is repelled by the atmoſphere of the tube; and if the excited tube be held juſt oppoſite to the point, the bruſh will entirely vaniſh, becauſe both the tube and the point are electrified poſitively. If the excited tube be brought near the point of the wire fixed upon the rubber, the ſtar upon it will turn itſelf towards the tube; for this wire, being electrified negatively, will attract the electric fluid of the excited tube.

If this experiment be repeated with an excited ſtick of ſealing-wax, or any other electric negatively electrified, inſtead of the glaſs tube, it will be found that the bruſh proceeding from the wire fixed upon the prime Conductor, will turn itſelf towards the excited wax, &c. and the ſtar upon the point of the wire negatively electrified, will be diverted from it, or entirely ſuppreſſed, if the excited ſtick of ſealing-wax be brought juſt oppoſite to the point.

EXPERIMENT XI.

A curious Method of ſhewing the Penetrability of electric Light.

Let the extremities of two wires, one of which proceeds from the outſide of a charged jar, and another from one branch of the diſcharging rod, be laid on a table at about $\frac{1}{10}$ of an inch diſtance of each other; then put the thumb juſt upon that interruption, preſſing it flat down. This done, bring the diſcharging rod in contact with the knob of the jar, and on making the diſcharge, the ſpark which neceſſarily happens under the thumb will illuminate it in ſuch a manner, that the bone, and the principal blood-veſſels, may be eaſily diſcerned in it.

In this experiment the operator needs not be afraid of receiving a ſhock; for the diſcharge of the jar paſſes from wire to wire, and only affects the thumb with a ſort of tremor, which is far from being painful.

EXPERIMENT XII.

To illuminate a Quantity of Water by the Diſcharge of a Jar.

Let every thing be diſpoſed in the manner mentioned in the preceding experiment, excepting only that, inſtead of the thumb, a large clear glaſs decanter full of water, having a flat bottom, be laid juſt over the interruption of the circuit. Then, on making the diſcharge, the water will be ſeen all illuminated to the very top of the decanter.

EXPERIMENT XIII.

To illuminate Ivory, Wood, &c.

Place a ball, or a thick piece of ivory, between the extremities of the wires of the univerſal diſcharger, and by connecting one of the wires with the outſide, and the other with the inſide of a charged electric jar, paſs the ſhock through the ſaid ball, and it will appear all illuminated.

If box wood be uſed inſtead of ivory, it will appear illuminated with yellow, red, purple, or crimſon colour.—Other ſorts of wood exhibit other ſhades of red or yellow, and ſometimes green; which varieties of colour ſeem to depend moſtly on the compactneſs of the wood, and on its degree of dryneſs.

EXPERIMENT XIV.

The electrified Capillary Syphon.

Let a ſmall bucket of metal, full of water, be ſuſpended from the prime Conductor, and put in it a glaſs ſyphon of ſo narrow an extremity, as the water will juſt drop from it. If in this diſpoſition of the apparatus the winch of the machine be turned, the water, which, when not electrified, only dropt from the extremity of the ſyphon, will now run in a full ſtream, which will even be ſubdivided into other ſmaller ſtreams; and if the experiment be made in the dark, it will appear beautifully illuminated.

EXPERIMENT XV.

The electrified Bells.

Fig. 10 of Plate II. represents an instrument having three bells, which are caused to ring by the power of electric attraction and repulsion. B is a brass piece furnished with a hook, by which it may be suspended from the rod proceeding from the extremity of the prime Conductor A. The two bells, C and E, are suspended by brass chains; but the middle bell D, and the two small brass clappers between C D, and D E, are suspended by silk threads. From the concave part of the bell D, a brass chain proceeds, which falls upon the table, and has a silk thread F at its extremity. The apparatus being disposed as in the figure, if the cylinder of the machine be turned, the clappers will fly from bell to bell with a very quick motion, and the bells will ring as long as they are electrified.

The two bells, C and E, being ſuſpended by braſs chains, are firſt electrified; hence they attract the clappers, communicate to them a little Electricity, and repel them to the unelectrified bell D, upon which the clappers depoſit their Electricity, and then run again to the bells C E, from which they acquire more Electricity, &c. If by holding the ſilk thread F, the chain of the middle bell be raiſed from the table, the bells, after ringing a little while, will ſtop, becauſe the bell D remaining inſulated, will ſoon become as ſtrongly electrified as either of the other two bells; in which caſe the clappers, having no opportunity of depoſiting the Electricity that they acquire from the bells C, E, muſt conſequently ſtop.

If this experiment be made in the dark, ſparks will be ſeen between the clappers and the bells.

The experiment will have a better effect, if, inſtead of keeping the machine in motion, a charged jar be ſet with its knob in contact with the prime Conductor.

EXPERIMENT XVI.

The Spider ſeemingly animated by Electricity.

Fig. 9 of Plate II. repreſents an electric jar, having a wire CDE faſtened on its outſide, which is bent ſo as to have its knob E as high as the knob A. B is an artificial ſpider made of cork, with a few ſhort threads run through it, to repreſent its legs. This ſpider is faſtened at the end of a ſilk thread, proceeding from the cieling of the room, or from any other ſupport, ſo that the ſpider may hang mid-way between the two knobs A, E, when the jar is not charged. Let the place of the jar upon the table be marked; then charge the jar by bringing its knob A in contact with the prime Conductor, and replace it in its marked place. The ſpider will now begin to move from knob to knob, and continue this motion for a conſiderable time, ſometimes for ſeveral hours.

The inſide of the jar being charged poſitively, the ſpider is attracted by the knob A, which

A, which communicates to it a ſmall quantity of Electricity; the ſpider then becoming poſſeſſed of the ſame Electricity with the knob A, is repelled by it, and runs to the knob E, where it diſcharges its Electricity, and is then again attracted by the knob A, and ſo on. In this manner the jar is gradually diſcharged; and when the diſcharge is nearly completed, the ſpider finiſhes its motion.

EXPERIMENT XVII.

The Spiral Tube.

Fig. 13 of Plate II. repreſents an inſtrument compoſed of two glaſs tubes CD, one within another, and cloſed with two knobbed braſs caps, A and B. The innermoſt of theſe tubes has a ſpiral row of ſmall round pieces of tin-foil, ſtuck upon its outſide ſurface, and lying at about one-thirtieth of an inch from each other. If this inſtrument be held by one of its extremities, and its other extremity be preſented to the prime Conductor, every ſpark that it receives from the prime Conductor, will

 cauſe

caufe fmalls fparks to appear between all the round pieces of tin-foil ftuck upon the innermoft tube, which in the dark affords a pleafing fpectacle; the inftrument appearing encompaffed by a fpiral line of fire.

The fmall round pieces of tin-foil are fometimes ftuck upon a flat piece of glafs, ABCD, fig. 12, fo as to reprefent curve lines, flowers, letters, &c. and they are illuminated after the fame manner as the fpiral tube; *i. e.* by holding the extremity C, or B, in the hand, and prefenting the other extremity to the prime Conductor, when the machine is in motion.

EXPERIMENT XVIII.

To make Holes through a Glafs Tube by means of Electric Sparks.

Let a glafs tube of any diameter, and about five or fix inches length, be clofed hermetically, or by means of fealing-wax, at one end, and fill about half of it with olive oil; then ftop the aperture of it with a cork, and let a wire pafs through the cork, and come fo far within the tube, as to have its extre-

mity below the ſurface of the oil. This end of the wire muſt touch the ſurface of the glaſs, for which purpoſe it muſt be bent nearly at right angles, which may be eaſily done before the cork is put upon the tube. Things being thus prepared, bend into a ring the other extremity of the wire, and ſuſpend it, with the tube hanging to it, to the wire at the end of the Conductor. Then work the machine, and bring the knuckle of a finger or the knob of a wire near the outſide of the tube, juſt oppoſite to the extremity of the wire; the conſequence of which will be, that a ſpark will happen between the wire and the knuckle, which makes a hole through the glaſs.—By turning the wire about, or raiſing and lowering it, many holes may be ſucceſſively made in the ſame tube, after the manner above deſcribed.

In this experiment it is very remarkable, that ſo ſmall a power as a ſimple electric ſpark ſhould perforate a hole through ſo hard a ſubſtance as glaſs; and ſometimes the thickneſs of the glaſs has been nearly a quarter of an inch.

Experiment XIX.

To cause the Quickſilver to riſe in a Thermometer by means of Electricity.

Fix a wooden ball to the wire that proceeds from the extremity of the prime Conductor, and place another like wooden ball on a wire or other Conductor that communicates with the earth, at about half an inch diſtance from the other ball; in which ſituation, it is clear that, when the machine is in action, a ſtream of electric fluid will paſs from one ball to the other. Now if you place the bulb of a mercurial thermometer in that ſtream, *viz.* between the two balls, you will find that the quickſilver in it will be gradually raiſed by the action of the ſtream; and if the machine is worked for ſome time, the mercury will be raiſed ſeveral degrees above its former ſtation.

N. B. For this experiment, the bulb of the thermometer muſt be quite detached from the ſcale, ſo that the ſcale may begin

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at leaſt three inches above it. The experiment anſwers beſt when the balls are of ſoft wood.

EXPERIMENT XX.

To let Sealing-Wax be ſpun into fine Threads by means of Electricity.

Stick a ſmall bit of ſealing-wax on the extremity of a wire, and warm it ſo as to be ready to drop; in the mean time let the electrical machine be worked; then ſtop the motion of the machine, and at the ſame time bring the hot ſealing-wax within four or five inches of the prime Conductor, moving it about in a winding direction, and you will find that the ſealing-wax throws ſeveral exceedingly fine threads to the prime Conductor, which appear like red wool.

This experiment anſwers beſt when the Conductor is covered with varniſh.

EXPERIMENT XXI.

The dancing Balls.

Fix a pointed wire upon the prime Conductor, with the point outward; then take a glaſs tumbler, graſp it with your hands, and preſent its inſide ſurface to the point of the wire upon the prime Conductor, while the machine is in motion: the glaſs in this manner will ſoon become charged; for its inſide ſurface acquires the Electricity from the point, and its outſide loſes its natural quantity of electric fluid through the hands, which ſerve as a coating.—This done, put a few pith-balls upon the table, and cover them with this charged glaſs tumbler. The balls will immediately begin to leap up along the ſides of the glaſs, as repreſented in fig. 15, Plate II. and will continue their motion for a conſiderable time.

In this experiment the pith-balls are attracted and repelled by the electric fluid ſurperinduced upon the inſide ſurface of the glaſs,

glaſs, which they gradually conduct to the table, or other conducting body upon which the glaſs is ſet; at the ſame time that the external ſurface of the glaſs acquires the electric fluid from the contiguous air.

EXPERIMENT XXII.

To promote the Evaporation of Fluids, by means of Electricity.

Take two equal pewter plates, and pour in each of them an equal quantity of water, juſt enough to cover their bottoms, and with the help of a pair of ſcales let them be made equal in weight. This done, put one of the plates upon an inſulated ſtool, communicating with the prime Conductor of the electrical machine, and ſituate the other plate in ſome other part of the room, where it may be in an equal degree of heat, and equally expoſed to the air as the other plate, but only out of the influence of Electricity. Let now the machine be put in action, ſo as to keep the prime Conductor, and the plate connected with it, ſtrongly electrified for about half an hour or longer. Then ſtop the machine,

chine, and weigh both the plates; it will be found, that the plate which has been electrified is the lighter: hence it is plain, that the electrization has promoted the evaporation of the water contained in it.

The same experiment may also be made with fruit, with animals, with plants, and, in short, with any thing that is actually evaporating; but in some such cases, the electrization should be continued much longer; and also other circumstances ought to be taken into account, in order to render the effect of Electricity both sensible and certain. This experiment is also attended with the same effect, whether the electrization is positive or negative; hence we have another reason to disbelieve that negative electrization produces any effects upon the human body, different from the positive. Mr. KOESTLIN, who a few years ago published a dissertation on the effects of Electricity upon some organic bodies, pretended to have found, that both animal and vegetable life were retarded by negative electrification; but I do not know whether the experiment was ever repeated by any body else.

elſe. The oddity and diverſity of effects ariſing from experiments apparently ſimilar, are ſuch, that no perſon, converſant with experimental philoſophy, ſhould poſitively affirm any new natural law, that is indicated by a few facts, which are moſtly of a dubious nature; eſpecially when many other conſiderations ſeem to ſhew the improbability of the aſſertion.

EXPERIMENT XXIII.

To ſhew that the Fluids of the Human Body are better Conductors of Electricity than Water.

Take a glaſs tube about one-fortieth of an inch in diameter, and nearly ſix inches long, or rather two ſuch tubes, exactly equal in length and diameter; and holding one of them with one extremity in water, let it be filled with that fluid. The water will ſoon fill the tube, in virtue of the capillary attraction; eſpecially if the tube be held inclined to the ſurface of the water. After the ſame manner let the other tube be filled with blood, or ſome other fluid of the human body. Now let an electric jar be charged, and the circuit through which the jar is to be

be diſcharged, let it be formed of one of theſe tubes; to the extremities of which ſlender wires may be fitted ſo as juſt to touch the fluid contained in it, and alſo the arms of a perſon that is deſirous of trying the experiment. In this manner, if the diſcharge of the jar be made ſeveral times, alternately changing the glaſs tube, *viz.* uſing once that filled with water, then the other filled with blood, and ſo on; it will be found that the ſhock is felt more ſenſibly when the glaſs tube filled with any fluid of the human body forms part of the circuit, than when the tube filled with water is uſed.

The perſon who tries this experiment need not be afraid of the ſhocks, becauſe their force is much weakened by going through the ſmall quantity of fluid contained in the glaſs tube. Beſides, the ſtrength of the ſhocks ſhould not be greater than may be juſt felt. It is only neceſſary to charge the jar always equally high, which is eaſily done by means of Mr. LANE's Electrometer, deſcribed in the preceding pages.

After

After the like manner the degree of conducting power of various ſubſtances may be aſcertained. Thus it may be obſerved, that ſea-water conducts better than freſh water, and that common freſh water conducts better than diſtilled water. The conducting power of ſome powders may be alſo tried in this manner.

EXPERIMENT XXIV.

To break ſmall Glaſs Tubes by means of an electric Shock.

Let ſome glaſs tubes be drawn with the help of a blow-pipe, nearly in the ſhape repreſented by AB, fig. 9, Pl. II. *viz.* narrow in the middle and larger towards their extremities. The diameter of the middle part ſhould not exceed one-twentieth part of an inch. Fill one of theſe tubes with water, after the manner deſcribed in the preceding experiment, and inſert two ſlender wires through both apertures, the extremities of which, in the tube, ſhould come within about one-tenth of an inch of each other.— This done, let the diſcharge of an electric jar be made through this tube, *viz.* by connecting

necting the ring of the wire A with the outſide of the jar, and the ring of the wire B with the inſide of the ſaid jar, and the tube will be broke with conſiderable violence. The ſame effect is produced when the tube is filled with any other liquor inſtead of water.

If the extremities of the wires within the tube are put ſo far from each other, as to exceed the diſtance at which the charge of the jar can leap in the form of a ſpark, then the glaſs tubes will not be broke.

By this experiment we can hardly deduce any inſtruction relative to the ſenſation of the ſhock perceived by a perſon, who forms the circuit in the diſcharge of an electric jar; for we learn by the experiment, that except any ſpark happens within the water, the fineſt and brittleſt tube is not broke; and therefore we may conclude, that the concuſſion given to the tube by the ſhock, when the extremities of the wires within it are conſiderably far from each other, is very little, if at all ſenſible.—Farther, it ſeems plain, that if inſtead of one tube, the diſcharge of the jar was made through one hundred

hundred or one thouſand tubes, the impulſe of the ſhock would be proportionably leſſened; and indeed we can hardly form any idea of the ſmallneſs of its power in that caſe. How happens it then that a very ſmall ſhock ſent acroſs the arms of a man, which ſhock, we may reaſonably ſuppoſe, does not occaſion any ſpark within the veſſels of the body, is ſenſibly felt, and produces an involuntary motion, when it paſſes through innumerable veſſels filled with fluids, which are far better conductors than water?

The ſubſtance of the veſſels of the human body is certainly a leſs good conductor than the fluids contained in thoſe veſſels; but it can hardly be ſuſpected, that the electric fluid occaſions the involuntary motion, &c. by going through that ſubſtance rather than through the fluids, which are much better conductors. Perhaps that ſudden involuntary motion is produced by the electric fluid acting upon the nerves. But it ſeems that, independent of the already known parts of the human body, there is ſome other principle that accompanies the life of an animal, which is in a certain man-

ner a conductor of electricity, and whose action ceases as soon as the animal becomes extinct. It has been remarked in several instances, that if an electric spark passes through a given part of a living animal, the same shock, after the animal is dead, will be visibly transmitted over the surface of the same part, but not through it.

Experiment XXV.

To crystallize Oil of Tartar by means of Electric Sparks.

Take a glass tube about four inches long, and about one quarter of an inch in diameter, open at both ends, and moisten the inside of it with oil of tartar *per deliquium*; then adapt two corks to the extremities of this tube, and introduce a wire through each of them. The extremities of these wires within the tube should be about three quarters or one inch from one another. This done, connect one of the wires with the outside coating of a pretty large electric jar, and the other wire with the discharging

electrometer;

electrometer; then let the jar be discharged several times through the tube; and it will be often found, that the oil of tartar upon the inside surface of the tube, gives manifest signs of crystallization. Now by experiments similar to this, some ingenious persons have pretended to shew, that the electric fluid contains an acid, which combining with the oil of tartar, neutralizes it, and occasions the crystallization.—It has even been said, that the phenomena of electricity are the effects of two principles, *viz.* an acid which constitutes the positive, and an alkali, which constitutes the negative electricity. It would be useless to endeavour to refute such an hypothesis, when a very little acquaintance with the subject is sufficient to manifest its absurdity. The crystallization has been with more justice attributed to a quantity of fixed air generated by the action of the shocks on the common air within the tube.

CHAP. XII.

Further Properties of the Leyden Phial, or charged Electrics.

THE properties of charged electrics, plain as they may appear at first sight, and conformable to the commonly-established theory of Electricity, are yet, when attentively considered, far from being intirely understood, so as to require no further experiments, or leave no doubt in the mind of the speculative Electrician. The first question, that naturally occurs, in considering a charged phial, is, Where does the superinduced electric fluid reside? ——Is it lodged in the substance of the glass, or in the air contiguous to the surface of the phial? In the first case, if the electric fluid penetrates a certain quantity of the substance of the glass, it follows, that a glass plate may be given so thin, that the electric fluid may freely pervade its substance,

ſtance*. If ſuch a plate can be made, it will be eaſy, from thence, to determine how far the electric fluid can penetrate the ſubſtance of the glaſs, when charged in the uſual manner. In the ſecond caſe, if the electric fluid reſides in the air contiguous to the glaſs, it muſt repel that air, *i. e.* a glaſs bottle ſhould contain leſs air when charged, than when in its natural ſtate; but this is contrary to experience.

The late Mr. CANTON charged ſome thin glaſs balls of about an inch and a half in diameter, having tubes of about nine inches in length, and afterwards ſealed them hermetically. If theſe balls, when they were cold, were preſented to an electrometer, they ſhewed no ſign of Electricity; but if they were kept a little while near the fire, they then appeared ſtrongly electrical, and poſſeſſed of that kind of Electricity with which their inſide had been charged.

* I have often blown glaſs balls ſo thin, that their ſubſtance was leſs than one ſix-hundredth part of an inch, and have always obſerved, that they were capable of receiving a charge, which they retained for a conſiderable time, if they were not made very hot.

Mr. CANTON discovered farther, that if these balls are kept under water, they retain their virtue for a considerable time, even for several years; but if they be often used, their power is soon exhausted. It is obvious to remark, that the Electricity, which appears upon the outside of these balls, when they are rendered hot, *i. e.* when the glass is rendered a Conductor by the heat, is not that Electricity, which properly constitutes the charge, but the superfluous Electricity of their inside *.

As for the Electricity, which constitutes the charge, it being just sufficient to balance the contrary Electricity of the oppo-

* If a charged jar be insulated, and discharged with an insulated discharging rod, after the discharge both the sides of the jar, together with the discharging rod, will be found possessed of the Electricity contrary to the Electricity of that side of the jar, which was touched last before the discharge; which shows that one side of a charged electric may contain a greater quantity of Electricity than that, which is sufficient to balance the contrary Electricity of the opposite side. This redundant Electricity should be carefully considered in performing experiments of a delicate nature.

site

fite ſurface of the glaſs, it will loſe its power as ſoon as it is arrived to that ſurface, which in the caſe of the above-mentioned balls, it actually reaches, before it can act upon the electrometer.

The moſt remarkable phenomena produced by charged electrics, are exhibited with flat plates of glaſs, jointly charged, like a ſingle coated plate. If two glaſs plates, having plain ſurfaces, be placed one upon the other, and their outward ſurfaces be coated with tin-foil, in the uſual manner of coating a ſingle plate for the Leyden experiment, and then be charged, by preſenting one coating to the prime Conductor, and communicating the other with the earth, the plates (which we ſhall call A, and B) after having been charged, will adhere very firmly to one another, and if ſeparated, A, *viz.* that, whoſe coating was preſented to the prime Conductor, will appear poſitive on both ſides, and B negative on both ſides. If theſe plates be laid in contact as before they were charged, and are diſcharged by making a communication between the two coated ſides, they will be found

found ſtill to adhere to one another after the diſcharge; and if ſeparated, they will appear ſtill electrified, but with this remarkable difference, *viz.* that now A is negative on both ſides, and B poſitive on both ſides. If theſe plates, after being diſcharged, be ſeparated in the dark, flaſhes of light are perceivable between their internal ſurfaces. By laying the plates together, touching their coatings, and ſeparating them ſucceſſively, the flaſhes may be obſerved for a conſiderable number of times, diminiſhing by degrees, until they quite vaniſh.

Father BECCARIA explains theſe, and other ſimilar phenomena of charged as well as of excited electrics, by the following principle, which he diſtinguiſhes by the name of *vindicating Electricity.*—When two bodies, either a Conductor and an electrified electric, or two contrarily and equally electrified electrics, are joined together, they adhere to each other, and their Electricities diſappear; but as ſoon as they are ſeparated, the electrics recover their Electricities *.

* See BECCARIA's Artificial Electricity, Part II. Sec. VI.

How far this principle can be of uſe to explain the phenomena of charged glaſs, &c. I will not take upon me to determine. It would exceed too far the limits of my work, if I were to enumerate and account for all the particulars minutely. When the principle is expreſſed, the ingenious reader may eaſily apply it to explain the effects. I ſhall only mention an obſervation of Mr. HENLY, relative to this ſubject, which ſeems not conformable to Father BECCARIA's theory; and with that I ſhall conclude this Part of my work. Says Mr. HENLY, in one of his papers preſented to the Royal Society, in which he deſcribes the above-mentioned experiments of the two glaſs plates:— "Crown-glaſs, that is, the glaſs commonly "uſed for ſaſh-windows, though ſo much "thinner, ſucceeds in this experiment as "well as the plate-glaſs; but what is very "remarkable, the Dutch plates, when "treated in the ſame manner, have each a "poſitive and negative ſurface, and the "Electricity of both ſurfaces of both plates "is exchanged for the contrary Electricity "in the diſcharge. If a clean, dry, uncoated "plate of looking-glaſs be placed between

"the coated looking-glaſs plates, or be-
"tween the plates of crown-glaſs, it ap-
"pears, after charging, to be negatively
"electrified on both ſides; but if it be
"placed between the Dutch plates it ac-
"quires, like them, a poſitive Electricity
"on one ſurface, and a negative Electricity
"on the other."

In another paper Mr. HENLY further obſerves, that if the Dutch plates be ſeparated immediately after being charged, they will then act like two plates of looking-glaſs, *i. e.* one of them will be poſitive, and the other negative, on both ſides; but if a little time be allowed before the plates be ſeparated, the experiment will conſtantly ſucceed as above*.

* To this, as well as to the third edition, a diſſertation on the *vindicating Electricity* has been added in the Appendix; which will ſhew, by plain experiments, this wonderful property of glaſs, &c. whilſt this chapter has been here reprinted juſt as it was publiſhed in the two preceding editions.

THE END OF VOL. I.

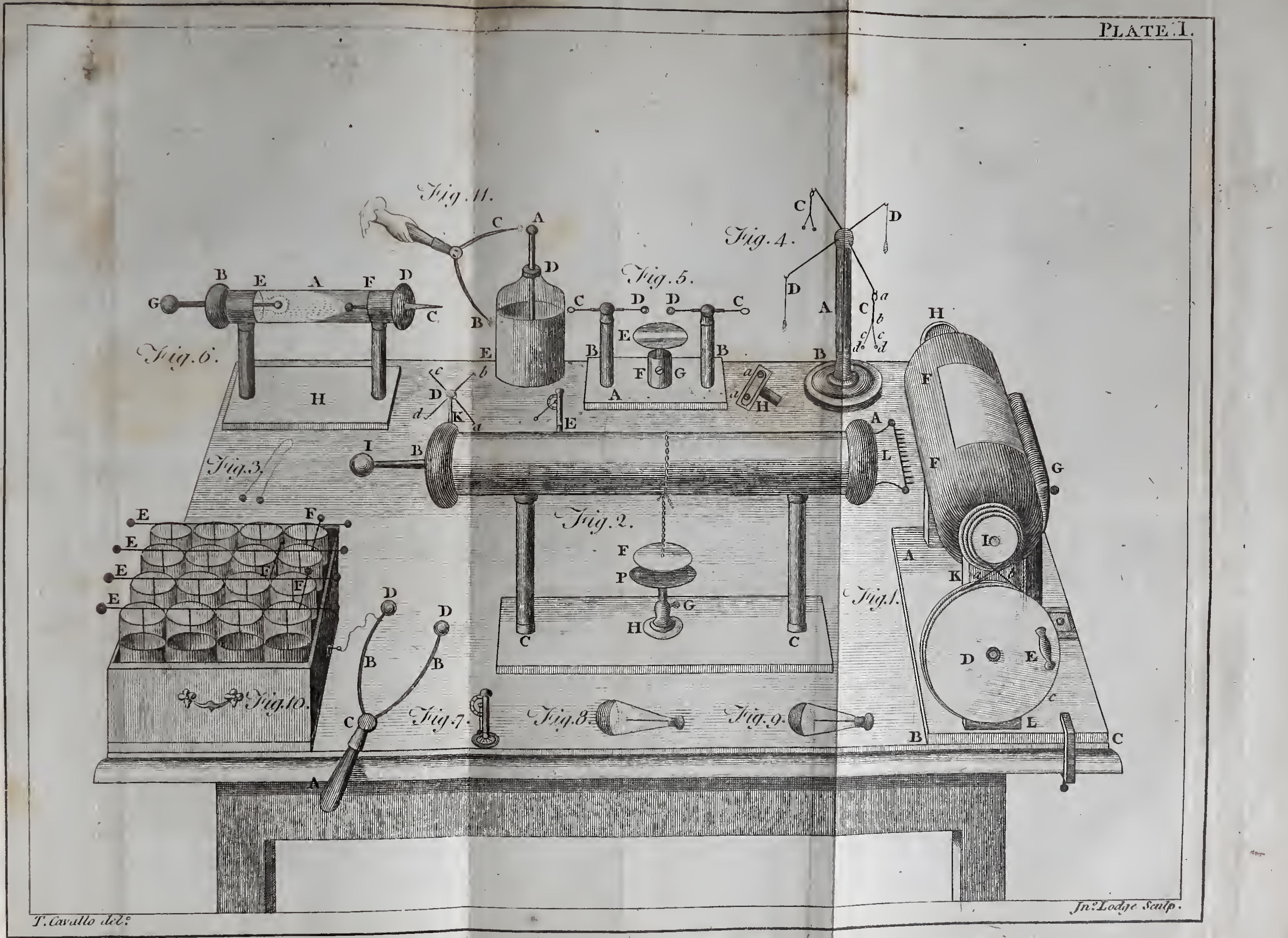
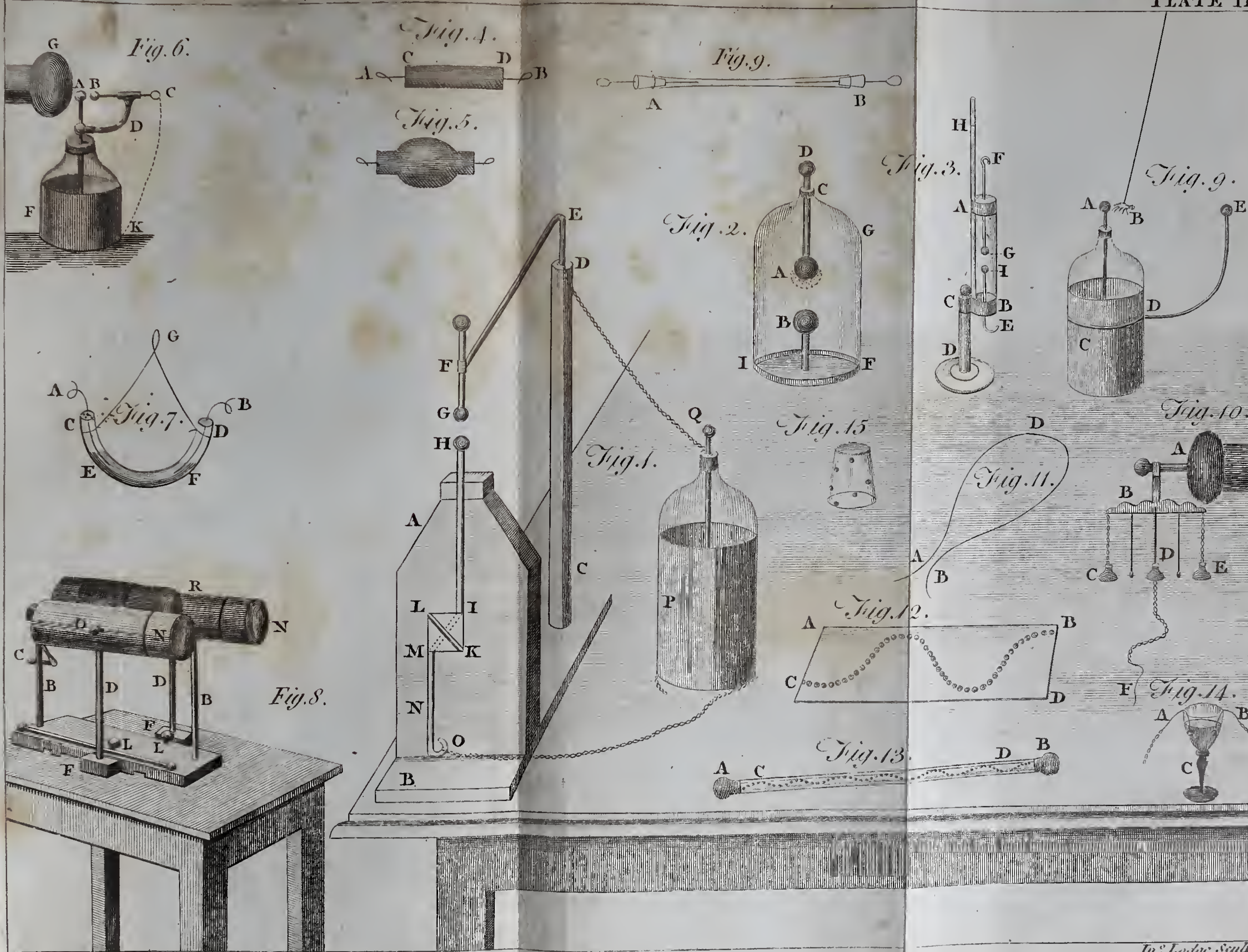


Fig. 11.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 3.
Fig. 2.
Fig. 1.
Fig. 10.
Fig. 7.
Fig. 8.
Fig. 9.
T. Cavallo del.
Jn. Lodge Sculp.

PLATE II.



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